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(71) Applicant: INNOGENETICS N.V.

9052 Gent (BE)

(72) Inventors:

• Cocito, Carlo

1340 Ottignies (BE)

• Coetsler, Christophe

5530 Spontin (BE)

Remarks:

- The applicant has subsequently filed a sequence listing and declared, that it includes no new matter.
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(54) **Polypeptides and nucleic acids encoding the same for the diagnosis and prevention of tuberculosis disease.**

(57) The invention relates to an isolated nucleic acid of *M. tuberculosis* containing in its nucleotide sequence at least two overlapping ORF's which encode the following two antigenic proteins, recognized by a pool of sera from tuberculous patients:

- (i) B2 protein represented by SEQ ID N0 2, or a protein homologous to B2 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID N0 2, and
- (ii) B3 protein represented by SEQ ID N0 3, or a protein homologous to B3 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID N0 3, or a fragment of said nucleic acid, said fragment containing at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence of said nucleic acid, and encoding at least one epitope of the B2 and/or B3 protein, or its homologues.

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## Description

[0001] The current invention relates to an isolated nucleic acid molecule of *M. tuberculosis*, encoding several antigenic polypeptides useful for the *in vitro* diagnosis and prevention of tuberculosis disease in mammals. The invention also relates to recombinant polypeptides encoded by said nucleic acid, methods for producing the same, and their use in methods and kits for the *in vitro* diagnosis of tuberculosis disease in mammals. The invention also relates to a vaccine for the prevention of tuberculosis disease in mammals, comprising as an active principle said nucleic acid or the polypeptides encoded thereby.

## BACKGROUND OF THE INVENTION

[0002] Tuberculosis is the infectious disease with the largest diffusion worldwide, affecting about one third of the world population. Its high morbidity (8 million new patients a year) and mortality (3 million deaths a year) rates witness the virulence of the etiological agents (*M. tuberculosis* and *M. bovis*).

[0003] Tuberculous bacilli are disseminated by post-primary tuberculosis patients with open lesions (Daniel, 1994; Youmans, 1985). The commonly used diagnostic procedures are unsatisfactory. Culturing the bacilli starting from a sample taken from the patient requires very long incubation times, while only mycobacteria with intact envelop are identified in biopsies by the Ziehl-Neelsen staining. These handicaps are not shared by the immunological diagnostic procedures (Daniel and Debanne, 1987). However, commercially available serological methods lack species-specificity, being unable to distinguish tuberculous bacilli from the other pathogenic and saprophytic mycobacteria. In fact, extensive homologies exist among the corresponding proteins of different mycobacterial species.

[0004] Numerous proteins of *M. tuberculosis* and *M. bovis* have been identified as immunologically significant for diagnosis, being recognized by patients sera and/or eliciting a cellular immune response. Most of them are secretory products, released by growing bacteria and thus directly interacting with the host immune system. Reference can be made to the review article of Young et al (1992) for the mycobacterial proteins described before 1992. Those more recently discovered have molecular weights of 6 (Sørensen et al. 1995; Pollock and Andersen, 1997), 10-14 (Boom et al., 1994), 16 (Verbon et al. 1992; Friscia et al., 1995), 18 (Manca et al. 1997), 19 (Harris et al. 1994, Prestidge et al. 1995), 25 (Hewinson et al. 1996), 26 (O'Loan et al., 1994), 28 (Berthet et al., 1995; Bigi et al. 1995), 29 (Laqueyrie et al., 1995), 30 (Sinha et al., 1997), 34 (Hermans et al., 1995), 45 (Romain et al., 1993), 66 (Deshpande et al., 1994) and 88 (Braibant et al., 1994; Laal et al., 1997) kDa.

[0005] A small number of mycobacterial protein genes have been cloned: the corresponding translation products have been characterized, and some of them have been used on an experimental scale for immunoassays. The heat-shock proteins of 14, 65, and 71 kDa of the tuberculous bacilli have been purified (Young et al. 1992): they cross-react, however, with the homologous proteins of other species, since they hold ancient motifs shared by even distantly-related bacteria (Young et al. 1987). Among the recombinant proteins biochemically characterized, those of 6 kDa (ESAT-6) (Sørensen et al., 1995), 18 kDa (MPT-63) (Manca et al., 1997), 19 kDa (Prestidge et al., 1995), 22 and 25 kDa (MPB83 and 70) (Hewinson et al., 1996; Matsumoto et al., 1995), 28 kDa (erp) (Berthet et al., 1995; Bigi et al., 1995), 29 kDa (Apa 45/47) (Laqueyrie et al., 1995), 30-32 kDa (Ag 85 A-B-C) (Borremans et al., 1989; Content et al., 1991), 34 kDa (Ag 84) (Hermans et al., 1995), 38 kDa (Singh et al., 1992), ought to be cited. Most of these proteins crossreact with the corresponding proteins of mycobacteria other than *M. tuberculosis*. None of them has been used so far as a reagent in commercially available diagnostic kits, or applied for large scale epidemiological investigation. Detection assays based on these antigens still lack sensitivity and/or specificity. In order to enhance sensitivity, a combination of different *M. tuberculosis* antigens will be indispensable. Specificity of the assay has to be increased by selecting peptides which specifically react with sera from *M. tuberculosis* (*M. bovis*) infected subjects and not with sera from healthy subjects, or subjects infected by mycobacteria other than *M. tuberculosis*. There remains a continuing need for new *M. tuberculosis* antigens, more particularly antigens containing *M. tuberculosis* species-specific epitopes useful in the immunodiagnosis of tuberculosis.

## AIMS

[0006] It is an aim of the current invention to provide new *M. tuberculosis* antigens useful in the immunodiagnosis of tuberculosis disease.

[0007] More specifically, it is an aim of the current invention to provide new *M. tuberculosis* polypeptides containing species-specific epitopes, useful in the serodiagnosis of tuberculosis disease.

[0008] It is moreover an aim of the current invention to provide the nucleic acids encoding said polypeptides. The sequence of said nucleic acids and their translation products is also provided by the current invention.

[0009] It is also an aim of the current invention to provide methods for producing said *M. tuberculosis* polypeptides.

[0010] It is moreover an aim of the current invention to provide methods and kits for immunodiagnosis of tuberculosis

disease in mammals.

[0011] Finally, it is an aim of the current invention to provide for a vaccine composition against tuberculosis disease.

[0012] It is believed that all the above-mentioned aims have been met by the different embodiments of the current invention.

## DEFINITIONS

[0013] The term "nucleic acid" or "polynucleic acid" refers to a single stranded or double stranded nucleic acid molecule which may contain from 10 nucleotides to the complete nucleotide sequence (such as for instance 20, 30, 40, 50, 60, 70, 80 or more nucleotides). A nucleic acid which is smaller than about 100 nucleotides in length is often also referred to as an oligonucleotide. A nucleic acid may consist of deoxyribonucleotides (DNA) or ribonucleotides (RNA), nucleotide analogues or modified nucleotides, or may have been adapted for therapeutic purposes. Nucleic acid molecules are represented throughout the current invention by single stranded DNA-sequences, extending from the 5' end to the 3' end. It should be understood however that the nucleic acids of the current invention also encompass the complementary strand of the illustrated molecule, as well as the double stranded molecules and the corresponding RNA molecules, wherein the deoxyribonucleotides are replaced by ribonucleotides, and wherein T is replaced by U.

[0014] The expression "isolated" means that the respective component (nucleic acid, protein) is preferably 90%, more preferably 95%, most preferably 98% pure as measured by its weight versus the weight of possible contaminants. For the isolated polypeptides of the invention, the purity is high enough in order to ensure a specific reactivity of the polypeptides with sera from tuberculous patients.

[0015] The term "Open Reading Frame (ORF)" refers to a nucleotide sequence containing a series of triplets coding for amino acids, without the occurrence of a termination codon. The sequence of an ORF is (potentially) translatable into a protein.

[0016] The term "polypeptide" designates a linear series of amino acids connected one to the other by peptide bonds between the alpha-amino and carboxy groups of adjacent amino acids. In the context of the present invention, the term "polypeptide" may be used interchangeably with the term "protein". Polypeptides can be in a variety of lengths, shorter polypeptides (i.e. of 50 amino acids in length or shorter), are usually termed "peptides". Polypeptides and peptides may occur either in their natural (uncharged) forms or in forms which are salts, and either free of modifications such as glycosylation, side chain oxidation, or phosphorylation or containing these modifications. It is well understood in the art that amino acid sequences contain acidic and basic groups, and that the particular ionization state exhibited by the polypeptide is dependent on the pH of the surrounding medium when the protein is in solution, or that of the medium from which it was obtained if the protein is in solid form. Also included in the definition are proteins modified by additional substituents attached to the amino acids side chains, such as glycosyl units, lipids, or inorganic ions such as phosphates, as well as modifications relating to chemical conversions of the chains, such as oxidation of sulfhydryl groups. Thus the polypeptides of the invention also include the appropriate amino acid sequence referenced subject to those of the foregoing modifications which do not destroy its functionality (i.e. immunoreactivity).

[0017] The polypeptides of the invention, and particularly the shorter peptides, can be prepared by classical chemical synthesis. The synthesis can be carried out in homogeneous solution or on solid phase.

[0018] For instance, the synthesis technique in homogeneous solution which can be used is the one described by Houbenweyl in the book entitled "Methode der organischen chemie" (Method of organic chemistry) edited by E. Wunsh, vol. 15-I et II. THIEME, Stuttgart 1974.

[0019] The polypeptides of the invention can also be prepared in solid phase according to the methods described by Atherton and Shepard in their book entitled "Solid phase peptide synthesis" (IRL Press, Oxford, 1989).

[0020] The polypeptides according to this invention can also be prepared by means of recombinant DNA techniques as described by Maniatis et al., (Molecular Cloning: A Laboratory Manual, New York, Cold Spring Harbor Laboratory, 1982), and as illustrated in the examples section.

[0021] The term "antigenic polypeptide" means that the polypeptide contains antigenic regions which induce a humoral (i.e. formation of antibodies) or a cellular immune response in the host organism which has been infected by the pathogen from which the polypeptide is isolated.

[0022] The term "immunogenic polypeptide" means that the polypeptide induces a protective immune response in the host organism. Immunogenic (poly)peptides are preferred reagents for vaccine compositions.

[0023] The term "immunodiagnosis" refers to the diagnosis of a disease by detection of a disease-specific immune response of the host organism. The immune response may be either of the humoral type (raise in antibody titer) or of the cellular type (specific lymphoproliferation, secretion of certain lymphokines...).

[0024] The term "serodiagnosis" refers to the diagnosis of a disease by the detection in the serum of a raised titer of specific antibodies against the pathogen.

[0025] The term "sensitivity" of an assay refers to the proportion of correctly identified patients. It is calculated as the ratio of "true positives" over the sum of "true positives" and "false negatives".

[0026] The term "specificity" of an assay refers to the proportion of healthy (=non-tuberculous) subjects that are serologically negative. It is calculated as the ratio of "true negatives" over the sum of "true negatives" and "false positives".

[0027] The term "epitope" or "antigenic determinant" refers to that portion of a molecule (in this case protein molecule) that is specifically bound by an antibody combining site. Epitopes may be determined by any of the techniques known in the art. They may be roughly predicted by a variety of computer prediction models known in the art. An epitope contains usually a stretch of at least 6 amino acids, preferably 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 30, 50 contiguous amino acids.

[0028] The expression "species-specific epitope" refers to an epitope which will only be recognized by antibodies raised against the respective species (organism). For example, a *M. tuberculosis* specific epitope will only be recognized by antibodies raised against the species *M. tuberculosis*, and not by antibodies raised against other types of mycobacteria. Species specificity may be evaluated using antibodies raised *in vitro* in laboratory animals, such as the technique used in the examples section (absorption technique). It may also be evaluated using antibodies present in sera from subjects who have been infected with the respective species.

[0029] It should be understood that in the context of the present invention the closely related species *M. tuberculosis* and *M. bovis* have to be considered as one single species, causing tuberculosis in mammals, and more particularly in man and bovine. It should be clear that, where the term *M. tuberculosis* is used, it encompasses in fact all the species belonging to the *M. tuberculosis* complex, and thus includes at least the following species: *M. tuberculosis*, *M. bovis*, *M. africanum*.

[0030] The expression "immunodominant epitope" refers to an epitope which is recognized by the majority of host immune systems. It means that, if a random set of sera from tuberculous patients is analysed, at least 30%, preferably 40%, and more preferably 50% or more of the sera recognize that particular epitope.

[0031] The expression "conservative amino acid substitution" means the substitution of an amino acid by a "related" amino acid, of which the side chain characteristics are comparable to the original amino acid. Table 1 shows a list of which substitutions are generally considered to be conservative.

TABLE 1

Overview of conservative amino acid substitutions.	
Amino acid	Conservative substitution by
Ser (S)	Thr, Gly, Asn
Arg (R)	His, Lys, Glu, Gln
Leu (L)	Ile, Met, Phe, Val, Tyr
Pro (P)	Ala, Thr, Gly
Thr (T)	Pro, Ser, Ala, Gly, His, Gln
Ala (A)	Pro, Gly, Thr
Val (V)	Met, Ile, Tyr, Phe, Leu
Gly (G)	Ala, Thr, Pro, Ser
Ile (I)	Met, Leu, Phe, Val, Tyr
Phe (F)	Met, Tyr, Ile, Leu, Trp, Val
Tyr (Y)	Phe, Trp, Met, Ile, Val, Leu
Cys (C)	Ser, Thr, Met
His (H)	Gln, Arg, Lys, Glu, Thr
Gln (Q)	Glu, His, Lys, Asn, Thr, Arg
Asn (N)	Asp, Ser, Gln
Lys (K)	Arg, Glu, Gln, His
Asp (D)	Asn, Glu, Gln
Glu (E)	Gln, Asp, Lys, Asn, His, Arg

TABLE 1 (continued)

Overview of conservative amino acid substitutions.	
Amino acid	Conservative substitution by
Met (M)	Ile, Leu, Phe, Val

## DETAILED DESCRIPTION OF THE INVENTION

[0032] The current invention provides for an isolated nucleic acid of *M. tuberculosis* containing a nucleotide sequence with a maximum length of 3000 contiguous nucleotides, wherein said nucleotide sequence contains at least two overlapping ORF's which encode at least a fragment of the following two antigenic proteins recognized by a pool of sera from tuberculous patients:

- (i) a B2 protein represented by SEQ ID NO 2, or a protein homologous to B2 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID NO 2, and
- (ii) a B3 protein represented by SEQ ID NO 3, or a protein homologous to B3 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID NO 3, or a fragment of said nucleic acid, said fragment containing at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence of said nucleic acid, and encoding at least one epitope of the B2 and/or B3 protein, or its homologues.

[0033] The amino acid sequence of protein B2 (SEQ ID NO 2) is shown in figure 2, and corresponds to the translation product of ORF1 (amino acid sequence shown below the nucleic acid sequence: position 1 to 626).

[0034] The amino acid sequence of protein B3 (SEQ ID NO 3) is shown in figure 2, and corresponds to the translation product of ORF2 (amino acid sequence shown above the nucleic acid sequence: position 1 to 513).

[0035] It is to be understood that the amino acid sequence of the protein homologous to B2 (or B3) differs from the sequence represented by SEQ ID NO 2 (respectively SEQ ID NO 3) by at least one conservative amino acid substitution as shown in Table 1. The percentage substitutions calculated over the total length of the polypeptide or peptide considered should not exceed 50%, and preferably is lower than 40%, most preferably lower than 30%, 20% or even lower than 10%. The homologous proteins of the invention are all recognized by sera from tuberculous patients.

[0036] The fragments of the above-described nucleic acid molecule should encode at least one epitope of the B2 and/or B3 protein. Preferably, the nucleic acid fragment encodes a *M. tuberculosis* (*M. bovis*) specific epitope of the B2 and/or B3 protein. The nucleic acid fragments of the invention contain a stretch of at least 15, preferably at least 30, more preferably at least 45 contiguous nucleotides of the sequence of the nucleic acid molecule as above-defined.

[0037] The B2 and B3 antigens described in the current invention form part of the thermostable macromolecular antigen complex (TMA) of *M. tuberculosis* (*M. bovis*), also termed A60. Purification of the A60 antigen of *M. bovis* BCG has been described before (Cocito et al., 1986; Cocito et al., 1991). The protein components of the TMA complex are responsible for its immunodominant character (Cocito et al., 1995; Fabre et al., 1986). The A60 antigen complex of *M. bovis* has been used as a reagent for an ELISA-type assay (Baelden et al., 1990) and cutaneous testing (Benoit et al., 1989) for the detection of tuberculosis. These assays proved to be able to correctly diagnose infection and to monitor development of disease (Carlucci et al., 1993; Zou et al., 1994a, 1994b). However, they lacked species-specificity, owing to the extensive cross-reactions among homologous proteins of different mycobacterial species (Coetsier et al., 1994).

[0038] The aim of the current invention was to identify those protein components of the A60 complex which contain immunodominant epitopes specific for the species *M. tuberculosis* (and *M. bovis*), to clone and sequence the corresponding gene(s), and to produce the proteins (or protein fragments) by recombinant DNA techniques. As will be shown in the examples section, this approach has enabled the identification of a *M. tuberculosis* genomic fragment containing two overlapping genes (b2 and b3), whose translation products are both recognized by tuberculous patients sera. The DNA segment including the two genes and their regulatory sequences has been cloned and sequenced, leading to the identification of two open reading frames (ORF 1 and 2), accounting for the synthesis of two proteins B2 and B3. The expression of the two genes from genetically engineered constructs has been demonstrated. Finally, the part of the B2 protein containing species-specific epitopes has been produced in *E. coli* by recombinant DNA techniques, it has subsequently been purified and used as a reagent in a serological assay (B2-ELISA) for the detection of tuberculosis.

[0039] According to a more specific embodiment, the invention provides for an isolated nucleic acid as defined above, wherein said nucleotide sequence is selected from:

- (i) the nucleotide sequence as represented in figure 2 (SEQ ID NO 1),
- (ii) a nucleotide sequence which hybridizes to the nucleotide sequence of (i) and which encodes a B2 protein, or a protein homologous to B2, and/or a B3 protein, or a protein homologous to B3, with said B2 (B3) protein and its homologues as defined above,
- (iii) a nucleotide sequence which is degenerate as a result of the genetic code to any of the nucleotide sequences as defined in (i) and (ii) and which encodes a B2 protein, or a protein homologous to B2, and/or a B3 protein, or a protein homologous to B3, with said B2 (B3) protein and its homologues as defined above, and
- (iv) a fragment of any of the nucleotide sequences as defined in (i) to (iii), said fragment containing a stretch of at least 15, preferably 30 and more preferably 45 contiguous nucleotides of any of the nucleotide sequences as defined in (i) to (iii), and encoding at least one epitope of the B2 and/or B3 protein, or the homologous proteins thereof.

It should be clear that the term "hybridizing" in point (ii) of the abovementioned embodiment refers to hybridization under stringent conditions, i.e. conditions allowing selective hybridization of nucleic acids which show at least 70% homology, preferably 80% homology, and most preferably 90%, or 95% homology.

[0040] The terms "homologous" and "homology" are used in the current invention as synonyms for "identical" and "identity"; this means that amino acid sequences which are e.g. said to be 55% homologous, show 55% identical amino acids in the same position upon alignment of the sequences. The same definition holds for homologous nucleic acid sequences, i.e. nucleic acid sequences which are e.g. said to be 55% homologous, show 55% identical basepairs in the same position upon alignment of the sequences.

[0041] According to a more specific embodiment, the invention provides for a nucleic acid as described above, containing or consisting of the nucleic acid sequence as represented in figure 2 (SEQ ID NO 1), or a fragment thereof said fragment containing a stretch of at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence represented by SEQ ID NO 1, and encoding at least one epitope of the B2 and/or B3 antigen.

[0042] More specifically, the invention provides for an isolated nucleic acid molecule as described above, containing a nucleotide sequence extending from position (x) to position (y) in the sequence of figure 2 (SEQ ID NO 1), with (x) and (y) representing any of the following values:

- from position (71) to position (1951),
- from position (398) to position (1951),
- from position (1063) to position (2604),
- from position (272) to position (1438),
- from position (1439) to position (1951),
- from position (1438) to position (2604),
- or a fragment of said nucleic acid, said fragment containing at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence of said nucleic acid, and encoding at least one epitope of the B2 and/or B3 antigen.

[0043] The above-defined nucleotide sequence stretches (x)-(y) encode the following polypeptides or polypeptide fragments:

- the nucleic acid fragment (71)-(1951) encodes the B2 protein in its longest form, i.e. starting from the first presumable start codon,
- the nucleic acid fragment (398)-(1951) encodes the B2 protein in its shorter form, i.e. starting from the second presumable start codon,
- the nucleic acid fragment (1063)-(2604) encodes the B3 protein,
- the nucleic acid fragment (272)-(1438) encodes the a390 fragment of the B2 protein, described further in the examples section,
- the nucleic acid fragment (1439)-(1951) encodes the a171 fragment of the B2 protein, described further in the examples section,
- the nucleic acid fragment (1438)-(2604) encodes the a389 fragment of the B3 protein, described further in the examples section.

[0044] According to another embodiment, the invention provides for a recombinant vector, for cloning and/or expression purposes, into which a nucleic acid as described above, or a fragment of said nucleic acid, has been inserted and

wherein, in case of an expression vector, the coding sequence of said nucleic acid is operably linked to an expression cassette enabling the expression of the coding sequence by a host cell.

[0045] The expression "operably linked" refers to a juxtaposition wherein the components are configured so as to perform their usual function. Thus, control sequences operably linked to a coding sequence are capable of effecting the expression of the coding gene.

[0046] The term "expression cassette" encompasses a cassette of elements enabling the correct transcription and translation of the encoded sequences by the host cell machinery: i.e. a promoter sequence, a ribosome binding site, and possibly also regulating sequences, or secreting signals.

[0047] The invention furthermore provides for a host cell transformed by a recombinant vector as described above, with said host cell being preferably a prokaryotic organism, preferably chosen from among the following group of organisms: *E. coli*, *Streptomyces* species, *Corynebacterium* species, such as e.g. *C. glutamicum*, or fast-growing *Mycobacterium* species, such as e.g. *M. smegmatis*.

[0048] Suitable vectors and host cell systems for expression and/or cloning of the nucleic acids of the invention are well known in the art of recombinant DNA technology (e.g. Sambrook et al., 1989; Bothwell et al., 1990), and will be exemplified furtheron.

[0049] According to a subsequent embodiment, the invention provides for a polypeptide encoded by any of the nucleic acids as described above, or a fragment thereof, said fragment being recognized by a pool of sera from tuberculous patients.

[0050] More particularly, the invention provides for a polypeptide as described above, having at least one of the following amino acid sequences:

(i) the amino acid sequence of protein B2 represented by SEQ ID NO 2,

(ii) the amino acid sequence of protein B3 represented by SEQ ID NO 3,

(iii) the amino acid sequence extending from position (110) to position (626) in SEQ ID NO 2,

(iv) the amino acid sequence extending from position (68) to position (456) in SEQ ID NO 2,

(v) the amino acid sequence extending from position (457) to position (626) in SEQ ID NO 2,

(vi) the amino acid sequence extending from position (126) to position (513) in SEQ ID NO 3,

or a fragment of any of the polypeptides according to (i) to (vi), said fragment consisting of a contiguous stretch of at least 6, preferably 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 30, 50 or more amino acids of the sequence represented by SEQ ID NO 2 or SEQ ID NO 3, and being recognized by a pool of sera from tuberculous patients.

[0051] According to a very specific embodiment, the invention provides for a peptide having at least one of the following amino acid sequences:

KGADVVDAGGSQHNHR (K-14-R peptide, SEQ ID NO 4), or  
GQPPSRRRGDRHQSTRR (G-17-R peptide, SEQ ID NO 5).

[0052] The peptides K-14-R and G-17-R correspond to an epitope region in the B2 (resp. B3) protein. The positions of both peptides are indicated on the sequence of figure 2 (boxed) and on the hydrophilicity patterns of figure 8 (resp. Figure 9).

[0053] According to another embodiment, the invention provides for a fusion protein comprising an amino acid sequence of a polypeptide as described above, or a fragment thereof, linked to a heterologous amino acid sequence.

[0054] The production of the recombinant polypeptides of the invention as fusion proteins may offer several advantages, such as e.g. enhanced expression levels of the polypeptides of the invention, or easiness of purification due to the presence of purification "tags", or a better presentation of the polypeptide on a solid surface. The heterologous part of the fusion protein may be cleaved off in a later stage using appropriate endoproteases, or it may remain attached to the polypeptides of the invention.

[0055] In order to carry out the expression of the polypeptides of the invention in bacteria, such as *E. coli*, the following steps are required:

- transformation of an appropriate bacterial host strain with a recombinant vector in which a nucleotide sequence coding for one of the polypeptides of the invention has been inserted (insert) under the control of the appropriate regulatory elements, particularly a promoter recognized by the polymerases of the bacterial host and an appropriate ribosome binding site (RBS), enabling the expression in said bacterial host of said nucleotide sequence,
- culture of said transformed bacterial host in conditions enabling the expression of said insert, and
- possibly, purification of the recombinant polypeptide.

[0056] The techniques for carrying out the expression of recombinant proteins in any of the other hosts as specified above are also well known in the art of recombinant expression technology.

[0057] The invention thus also provides for a method for the production of a recombinant polypeptide as described above, or a fusion protein as described above, comprising at least the following steps:

- culturing a transformed cellular host as described above under conditions allowing the heterologous expression of the polypeptide which is encoded,
- isolating the polypeptide from the culture broth.

[0058] According to another embodiment, the invention provides for an antibody raised against a polypeptide as described above, more preferably a monoclonal antibody. Antibodies according to the invention include specific polyclonal antisera prepared against the *M. tuberculosis* polypeptides of the invention, and having no cross-reactivity to other proteins. The antibodies according to the invention specifically include monoclonal antibodies raised against the *M. tuberculosis* polypeptides of the invention.

[0059] The monoclonal antibodies of the invention can be produced by any hybridoma liable to be formed according to classical methods from splenic cells of an animal, particularly of a mouse or rat, immunized against the polypeptides of the invention on the one hand, and of cells of a myeloma cell line on the other hand, and to be selected by the ability of the hybridoma to produce the monoclonal antibodies recognizing the polypeptides which have been initially used for the immunization of the animals.

[0060] The monoclonal antibodies according to this preferred embodiment of the invention may be humanized versions of the mouse monoclonal antibodies made by means of recombinant DNA technology, departing from the mouse and/or human genomic DNA sequences coding for H and L chains or from cDNA clones coding for H and L chains.

[0061] Also fragments derived from these monoclonal antibodies such as Fab, F(ab)<sub>2</sub> and ssFv ("single chain variable fragment"), providing they have retained the original binding properties, form part of the present invention. Such fragments are commonly generated by, for instance, enzymatic digestion of the antibodies with papain, pepsin, or other proteases. It is well known to the person skilled in the art that monoclonal antibodies, or fragments thereof, can be modified for various uses.

[0062] The antibodies of the current invention can be labelled by an appropriate label of the enzymatic, fluorescent, or radioactive type.

[0063] According to another embodiment, the invention provides for a method for the *in vitro* detection of tuberculosis disease in a mammal subject, based on the detection of anti- *M. tuberculosis* antibodies present in a sample taken from said subject, comprising the steps of

- contacting said sample with a polypeptide as described above, or with a fusion protein as described above, under conditions allowing the formation of an immunological complex, and
- detecting the presence of an immunological complex formed between said polypeptide and the anti- *M. tuberculosis* antibodies which may be present in said sample.

[0064] It is to be understood that the detection of anti- *M. tuberculosis* antibodies in a serum sample is an indication of tuberculosis disease.

[0065] Preferably said mammal is a human subject, or a bovine animal.

[0066] The sample may be any body fluid possibly containing antibodies against *M. tuberculosis*, such as cerebrospinal fluid, serum, blood, plasma, milk, urine... Preferably, the sample is serum.

[0067] Conditions allowing the formation of an immunological complex are known to the person skilled in the art.

[0068] According to an alternative embodiment, the invention provides for a method for the *in vitro* detection of tuberculosis disease in a mammal subject, based on the detection of *M. tuberculosis* antigens present in a sample taken from said subject, and comprising the steps of

- if necessary, pretreatment of said sample in order to release the *M. tuberculosis* antigens which may be present in said sample,
- contacting said sample with an antibody as described above, under conditions allowing the formation of an immunological complex, and
- detecting the presence of an immunological complex formed between said antibody and the *M. tuberculosis* antigens which may be present in said sample.

[0069] It is to be understood that the detection of *M. tuberculosis* antigens in a sample is an indication of tuberculosis disease.

[0070] Design of immunoassays suitable for detection of antibodies or antigens in a sample, is subject to a great deal



of variation, and many formats are known in the art. Most assays involve the use of labeled antibody and/or polypeptide. The labels may be, for example, enzymatic (like horse radish peroxidase, alkaline phosphatase), fluorescent, chemoluminescent, radioactive, or dye molecules. In an enzyme linked immuno sorbent assay (ELISA) the label is enzymatic, and the detection signal is usually colorimetric (optical density).

5 [0071] Different types of ELISA may be feasible for detection of antibodies in a sample. In an indirect ELISA the polypeptides of the invention are coated on a solid surface (microtiter plates) where they capture the antibodies possibly present in the sample. The bound antibodies from the sample are subsequently detected by a labeled second antibody (conjugate). The signal generated by the latter is quantified.

10 [0072] In an antigen sandwich ELISA, the polypeptides of the invention are used twice, first as a capturing agent (bound on the surface of e.g. a microtiter plate) and secondly as a detecting agent (labelled polypeptide reacting with the bound antibodies from the sample). The antibodies from the sample are "sandwiched" between two layers of peptide (this is made possible by the two antigen binding sites which are present on each antibody).

15 [0073] In an antibody sandwich ELISA, the antibodies of the invention are used twice, first as a capturing agent (bound on the surface of a solid phase) and secondly as a detecting agent (labelled antibody reacting with the bound antigen from the sample). The antigens to be detected from the sample are "sandwiched" between two layers of antibodies.

[0074] According to a preferred embodiment, the invention provides for an immunodetection method or assay as described above, wherein said method or assay is an ELISA.

20 [0075] According to another embodiment, the invention provides for an immunodiagnostic kit for the *in vitro* detection of tuberculosis disease in mammals, said kit comprising a polypeptide as described above, or a fusion protein as described above, or an antibody as described above.

[0076] According to a more specific embodiment, the invention provides for an immunodiagnostic kit for the *in vitro* detection of tuberculosis disease in mammals, based on the detection of anti- *M. tuberculosis* antibodies present in a sample taken from said mammal, said kit comprising a polypeptide as described above, or a fusion protein as described above, possibly in combination with other *M. tuberculosis* antigens.

25 [0077] In a preferred embodiment, the immunodiagnostic kit comprises a solid support onto which the polypeptide of the invention has been readily immobilized.

30 [0078] The solid support onto which the polypeptides of the invention are coated may be chosen from the supports commonly used in the art of immunodiagnosis. Depending on the type of assay the solid support may be a polystyrene carrier (microtiter plate (e.g. ELISA) or beads (e.g. microbeads assay)), a nylon membrane (LIA (Line Immuno Assay)), latex beads (coagulation tests), etc. If different polypeptides are used simultaneously as detecting reagent, they may be coated either on different locations of the solid support, or together, on the same location.

[0079] The present invention relates more particularly to a kit for determining the presence of anti- *M. tuberculosis* antibodies in a biological sample liable to contain them, comprising:

- 35
- at least one polypeptide as defined above, preferentially in combination with other polypeptides or peptides from *M. tuberculosis*, with said polypeptides being preferentially immobilized on a solid substrate,
  - a buffer or components necessary for producing the buffer enabling a binding reaction between these polypeptides and the antibodies against *M. tuberculosis* present in the biological sample,
  - 40 - means or reagents for detecting (i.e. generating a detectable signal from) the immune complexes formed in the preceding binding reaction,
  - possibly also including an automated scanning and interpretation device for inferring the presence of *M. tuberculosis* antibodies in the sample from the detected signal.

45 [0080] According to another embodiment, the invention provides for a diagnostic kit for the detection of *M. tuberculosis* antigens in a sample, said kit comprising an antibody as described above.

50 [0081] According to yet another embodiment, the present invention relates to a method using at least one of the polypeptides of the invention, possibly in combination with other *M. tuberculosis* polypeptides, for measuring a cellular immune response in an individual which has been in contact with the *M. tuberculosis* pathogen, said cellular immune response being measured either *in vivo*, such as a delayed type hypersensitivity reaction upon subcutaneous injection of the polypeptides of the invention, or *in vitro*, such as the stimulation of peripheral blood lymphocytes or the secretion of certain lymphokines or cytokines (e.g. interferon-gamma), upon addition of the polypeptides of the invention to a sample of peripheral blood lymphocytes under conditions allowing recognition of the polypeptides by the cells responsive for the immune response, conditions which are known to the person skilled in the art.

55 [0082] It is to be understood that the presence of a cellular immune response against *M. tuberculosis* antigens in a subject, indicates that the subject has been in contact with the *M. tuberculosis* pathogen. It is an indication of a protective immune response which has been mounted against the pathogen, and it is not necessarily an indication of tuberculosis disease. This is in contrast with the presence of anti-*M. tuberculosis* antibodies, or the presence of *M.*

*tuberculosis* antigens in a sample, which do indicate the presence of tuberculosis disease in the subject from which the sample was taken, as described above.

[0083] The invention also provides for a vaccine composition for the prevention of tuberculosis disease in mammals, said vaccine composition comprising as an active principle a polypeptide as described above, or a fusion protein as described above, or a nucleic acid as described above, or a recombinant vector as described above, said active principle being combined with a pharmaceutically acceptable carrier.

[0084] Besides the *M. tuberculosis* polypeptides according to the invention, said vaccine composition may comprise also any other *M. tuberculosis* immunogenic component or any other bacterial or other immunogenic component in general.

[0085] In a specific embodiment, the nucleic acid encoding any of the polypeptides as defined above, is used as a vaccine, either as naked DNA or as part of recombinant vectors. In this case, it is the aim that said nucleic acid is expressed into immunogenic protein / peptide *in situ* in the vaccinated host and thus confers *in vivo* protection (e.g. Ulmer et al., 1993).

[0086] The active ingredients of such a vaccine composition may be administered orally, subcutaneously, conjunctivally, intramuscularly, intranasally, or via any other route known in the art including for instance via the binding to carriers, via incorporation into liposomes, by adding adjuvants known in the art, etc.

#### FIGURE LEGEND

[0087]

**Figure 1.** Immunoblot analysis of recombinant polypeptides produced by the ZAP-Tb22 phage. Proteins obtained, upon IPTG-induction, from the lysis plaques were separated by acrylamide gel electrophoresis (12% SDS-PAGE), and transferred to nitrocellulose membranes, which were either stained with colloidal gold (lane B), or incubated with a pool of tuberculous patients sera (lane C). Molecular weight markers are in lane A.

**Figure 2.** Nucleotide sequence (SEQ ID NO 1) of the overlapping genes b2 and b3 encoding the B2 and B3 proteins of *M. tuberculosis*. The nucleotide sequence shown in this figure contains two open reading frames of 1878 (ORF1) and 1539 (ORF2) nucleotides. The putative initiation codons and ribosomal binding sites are indicated in bold characters. Promoter-like sequences are underlined. The b2 and b3 genes encode proteins of 626 and 513 aa respectively, whose deduced amino acid sequences are displayed. The lower amino acid backbone represents the protein B2 (SEQ ID NO 2). The upper amino acid backbone represents the protein B3 (SEQ ID NO 3). H\* indicates the first amino acid residue encoded by the *M. tuberculosis* DNA insert within the ZAP-Tb22 phage. The EcoR1 and Sal1 restriction sites used for subcloning are underlined. The protein fragments a390, a171 and a389 which have been expressed in *E. coli* are indicated with arrows. The peptides K-14-R (B2) and G-17-R (B3) are boxed. The position of the nucleic acid region hybridizing to the Tbbiot1 probe is also indicated (double underlined).

**Figure 3.** Schematic diagram of subclones used for expression and/or sequencing of portions of the b2 and b3 genes.

(a) Scheme of the Tb22 DNA insert indicating the positions of the ORF 1 and 2, and of the main restriction sites (EcoR1=E, Sal1=S, Kpn1=K, BamH1=B, Pst1=P) used for subcloning.

(b) The 1170-bp EcoR1 fragment of Tb22 was ligated into the EcoR1 site of pmTNFIHXH, yielding the pmTNF.XH.a390 plasmid carrying the first 390 codons of ORF1, under the control of the pl lambda promoter. The insert of the plasmid is shown in shaded box.

(c) (d) The adjacent 2411-bp EcoR1 fragment was ligated into the EcoR1 site of pmTNFIHXH and pmTNFIIHXH. The resulting plasmids, carried the terminal 171 codons of ORF1 (pmTNF.XH.a171), and the 389 carboxyl-terminal codons of ORF2 (pmTNF.XH.a389), respectively, under the control of the pl lambda promoter. The inserts of the plasmids are shown in shaded boxes.

(e) position of the Tb3 clone (Pst1-Sal1) carrying the upstream region and presumptive starting codons of the b2 gene.

(f) position of the region of which the nucleic acid sequence is illustrated in figure 2.

**Figure 4.** Western blot analysis of the recombinant polypeptide a171. Crude cell extracts from *E. coli* cells containing the pmTNF.XH.a171 plasmid were heat-shocked at 42°C, fractionated by 12% SDS-PAGE, transferred to nitrocellulose membranes, and reacted with a pool of tuberculosis patient sera, preabsorbed (lane B') or not (lane B) with a *M. avium* lysate. Lane A': lysate of *E. coli* DH5α carrying no mycobacterial insert (negative control). Lane A: molecular mass standards.

**Figure 5.** Western blot analysis of the recombinant polypeptide a389. Crude cell extracts from *E.coli* cells containing the pmTNF.XH.a389 plasmid were heat-shocked at 42°C, fractionated by 12% SDS-PAGE, transferred to nitro-cellulose membranes, and reacted with the pool of tuberculosis patients sera, preabsorbed (lane B') or not (lane B) with *M.avium* lysates. Lane A' : lysate of *E.coli* DH5α carrying no mycobacterial insert (negative control). Lane A : molecular mass standards.

**Figure 6.** Electrophoretic analysis of the proteins expressed by recombinant *E. coli*, containing the plasmid pmTNF.XH.a171. The inclusion bodies fraction from recombinant *E.coli* SG4044 cells (containing the pmTNF.XH.a171 plasmid that codes for the carboxyl-terminal portion of protein B2) were isolated. Dissociated proteins were fractionated by electrophoresis (12% SDS-PAGE), and stained with Coomassie blue. (A) total cell lysate; (B) inclusion bodies.

**Figure 7.** Comparative serological analysis of healthy (BCG vaccinated and non-vaccinated) and tuberculosis patients sera by the A60 and the a171 ELISA assays. The absorbance values ( $A_{492nm}$ ) are reported on the ordinate axis. The horizontal lines represent the cutoff values. Different types of tuberculous (tbc) patients sera were considered: tbc post-primary (= patients who relapse after a previous tb-infection), tbc miliary (=patients with disseminated form of the disease throughout the body), tbc meningitis (=patients from which tuberculous bacilli have been isolated from the cerebrospinal fluid), tbc sera mixed (=patients with tuberculous infection of different organs, besides a pulmonary tuberculosis).

**Figure 8:** Hydrophilicity pattern of the B2 protein. Hydrophilicity values on the ordinate axis are calculated by the combined methods of Parker et al. 1986 (hydrophilicity *sensu strictu*), Karplus et al. 1985 (flexibility) and Janin, 1979 (accessibility). The region of the peptide K-14-R is indicated in black. Position 1 in this figure corresponds to amino acid position 455 in the B2 protein sequence as shown in figure 2.

**Figure 9:** Hydrophilicity pattern of the B3 protein. Hydrophilicity values on the ordinate axis are calculated by the combined methods of Parker et al. 1986 (hydrophilicity *sensu strictu*), Karplus and Shultz, 1985 (flexibility) and Janin, 1979 (accessibility). The region of the peptide G-17-R is indicated in black. Position 1 in this figure corresponds to amino acid position 125 in the B3 protein sequence as shown in figure 2.

**Figure 10:** Map of the pmTNFIXH plasmid used for expression of the polypeptides of the invention as a N-terminal fusion protein with the first 25 amino acids of mTNF. The plasmids pmTNFIIXH and pmTNFIIIXH are identical to pmTNFIXH except for the sequence of the polylinker site which contains one (pmTNFIIXH) or two (pmTNFIIIXH) additional nucleotides, allowing the translation of the different reading frames (I, II, III) of an inserted nucleic acid molecule. A detail of the nucleotide sequence of the polylinker site for the three different plasmids is given below:

polylinker site of pmTNFIXH:

5 ... CAG GGA ATT CGA GCT CGG TAC CCG GGG AGG CCT GCA CGT GAT CGA  
 aa 25 mTNF EcoRI Sac I KpnI SmaI StuI PmlI  
 GGG CAG ACA CCA TCA CCA CCA TCA CTA ATA GTT AAT TAA CTG CAG GGA  
 10 TCC TCT AGA GTC GAC CGG CAT GCA AGC TTA AGT AAG TAA ...  
 BamHI XbaI Sall SphI HindIII PacI PstI

15 (SEQ ID NO 7)

polylinker site of pmTNFIIXH:

20 ... CAG CCG AAT TCG AGC TCG GTA CCC GGG GAG GCC TGC ACG TGA TCG  
 aa 25 mTNF EcoRI Sac I KpnI SmaI StuI PmlI  
 25 AGG GCA GAC ACC ATC ACC ACC ATC ACT AAT AGT TAA TTA ACT GCA GGG  
 XbaI HindIII PstI  
 30 ATC CTC TAG AGT CGA CCG GCA TGC AAG CTT AAG TAA GTA A ...  
 BamHI Sall SphI PacI

35 (SEQ ID NO 8)

polylinker site of pmTNFIIXH:

40 ... CAG CCC GAA TTC GAG CTC GGT ACC CGG GGA GGC CTG CAC GTG  
 aa 25 mTNF EcoRI Sac I KpnI SmaI StuI PmlI  
 45 ATC GAG GGC AGA CAC CAT CAC CAC CAT CAC TAA TAG TTA ATT AAC TGC  
 XbaI HindIII PstI  
 50 AGG GAT CCT CTA GAG TCG ACC GGC ATG CAA GCT TAA GTA AGT AA ...  
 BamHI Sall SphI PacI

55 (SEQ ID NO 9)

## EXAMPLES

**I. Materials and methods**

[0088] **Bacterial strains.** The following mycobacteria were used: *M. tuberculosis* H37Rv, MAIS ATCC-10708, MAIS ATCC-10719, *M. avium* D4 (from F. Portaels, Institute of Tropical Medicine, Antwerp, Belgium) and *M. scrofulaceum* 82/549 (from M. Weckx, Pasteur Institute, Brussels, Belgium). A *M. leprae* preparation was provided by the World Health Organization (WHO, Geneva, Switzerland).

[0089] The strains of *Escherichia coli* K-12 DH5 $\alpha$ F' (Life Technologies, Gaithersburg, Md.), XL1-Blue MRA (Stratagene, La Jolla, Calif.) and SG4044 (Innogenetics, Ghent, Belgium) were used as hosts for cloning and/or expression.

[0090] **Antibodies and sera.** Sera from tuberculosis patients were obtained from the Pneumology Department, Mt. Godinne Clinics, Belgium. Five sera from human immunodeficiency virus-negative postprimary tuberculosis cases under chemotherapy were pooled and used for serological screening.

[0091] Polyclonal rabbit antibodies against the peptides K-14-R (from B2 protein) and G-17-R (from B3 protein) were raised according to the techniques well known in the art. The peptides were coupled with KLH carrier protein (Neosystem Labs, Strasbourg, France). Conjugate KLH-peptides (500  $\mu$ g) emulsified with incomplete Freund's adjuvant were subcutaneously inoculated to rabbits twice, at two weeks interval. Sera were taken two weeks after the second injection. They were tested by Western blot analysis on BCG lysates (results not shown).

[0092] **Serum absorption.** At all stages of the work, sera were previously absorbed on lysates of *E. coli* K-12 (the cloning host). To identify species specific epitopes, cross-reacting antibodies were eliminated by absorption on lysates of atypical mycobacteria. Sera diluted (1/50) in TBS buffer (0.15 M NaCl, 0.10 M Tris-HCl [pH 7.5] containing 0.05 % [vol/vol] Tween 20, 10 mM phenylmethylsulfonyl fluoride, and 1 % [wt/vol] gelatin) were incubated overnight at 4°C with bacterial lysates (5 mg [dried weight] per ml of diluted serum). Absorption efficiency was controlled by dot-blot for Western blot analysis, and by ELISA for serological testing.

[0093] **DNA techniques.** Chromosomal DNA from *M. tuberculosis* H37Rv was prepared as previously described (De Kesel et al. 1993). Purification of phage DNA, DNA digestion, ligation, transformation of *E. coli* cells with plasmid, and infection with phage DNA were carried out according to Sambrook et al. (1989). The boiling miniprep method (Holmes et al. 1981) was used to screen restriction endonuclease segments of plasmid DNA. Large-scale preparation of *E. coli* plasmid DNA was made using a Qiagen-tip 500 kit (Westburg b.v., Leusden, Netherlands). Restriction enzymes and T4 DNA ligase were purchased from Boehringer (Mannheim, Germany). Restriction endonuclease fragments were purified from agarose gels with Nucleotrap kit (Macherey-Nagel, Düren, Germany).

[0094] Screening of bacteriophage plaques and Southern blot analysis (Sambrook et al., 1989), were done with the biotinylated DNA probe Tbbiot1 (5'-bGCGGGCGTTTCGGCTTCACC (SEQ ID NO 6)) and nylon membranes (Hybond-N+, Amersham, Buckinghamshire, UK).

[0095] **Nucleotide sequence analysis.** For analysis of DNA sequences, appropriate restriction fragments of cloned inserts were subcloned within the polylinker sites of pBluescript SK<sup>-</sup> (Stratagene, La Jolla, California). Subclone sequences were determined by the dideoxy chain termination method by using the Taq Dye Deoxy Terminator Cycle sequencing kit and a ABI 373a DNA sequencer (PE Applied Biosystems, Foster City, CA). The complete sequence was obtained with the M13 forward and reverse primers.

[0096] **Expression of ORFs by *E. coli*.** Recombinant plasmids were introduced in *E. coli* SG 4044 by transformation. Single transformed colonies were grown at 28°C in the presence of tetracycline to an A<sub>600</sub> of 0.2, and then heat shocked (4h, 42°C). Cell lysates were mixed with 4x SDS gel-loading buffer and analyzed by Western blot.

[0097] **Purification of a171 polypeptide.** *E. coli* SG 4044 cells containing the pmTNF-a171 plasmid, were concentrated by centrifugation and lysed by the lysozyme-plus-detergent procedure. The inclusion bodies were pelleted by centrifugation, washed with Triton X-100 and EDTA, and solubilized with 8 M urea (Sambrook et al. 1989).

[0098] **SDS-PAGE and Western blot analysis.** Different protein samples (lysis plaques, or cell lysates, or a171 polypeptide) in gel loading buffer, were boiled at 100°C for 5 min and loaded on 12 % polyacrylamide gels. Protein fractionation was carried out at a constant current of 30 mA in a vertical electrophoresis unit (gel 16 by 18 cm, Hoefer Scientific Instruments, San Francisco, Cal.). Electrophoresed components were transblotted (LKB 217 Multiphor 2, Bromma, Sweden, 100 mA, 2 h, with buffer containing 20 % methanol, 0.039 M glycine and 0.048 M Tris base pH 8.8) onto nitrocellulose membranes (BA 85, Macherey-Nagel, Germany). Total proteins were stained by colloidal gold (Auro-dye forte, Amersham, UK). Tuberculosis-specific proteins were visualized by sequential incubation with a pool of tuberculosis patients sera and with peroxidase-labeled anti-human immunoglobulins.

## **II. Isolation and characterization of the DNA fragment containing the b2 and b3 genes of *M. tuberculosis***

[0099] **Construction and immunological screening of a *M. tuberculosis* genomic library.** A genomic library of *M. tuberculosis* H37Rv was constructed as previously described (De Kesel et al. 1993). Mycobacterial DNA fragments

of 2 to 5 kb were ligated with lambda ZAPII (Stratagene, La Jolla, Calif.), by using *EcoRI* linkers. Recombinant lambda phages from the unamplified genomic library were plated according to manufacturers directions. After incubation at 42°C, when lysis plaques were just seen, plates were covered with nitrocellulose filters saturated with isopropyl-β-D-thiogalactopyranoside (IPTG), and incubated overnight at 37°C. Filters were washed with TBS buffer (0.15 M NaCl, 0.01 M Tris-HCl pH 7.5), incubated with the same buffer containing 2 % gelatin, and then for 12 h with a pool of 5 tuberculosis patients sera diluted (1/20) in TBST buffer (TBS buffer containing 0.05 % Tween 20 and 1 % gelatin). Bound human Ig were revealed with an anti-human-Ig second serum conjugated with horse peroxidase (Dako, Copenhagen, Denmark). Immunoreactive lysis plaques were detected with chloro-1-naphthol (Rio Rad Laboratories, Richmond, Calif.) and H<sub>2</sub>O<sub>2</sub> (0.015%). The plaques corresponding to the reactive spots on the filters were transferred to SM medium (100 mM NaCl, 10 mM MgSO<sub>4</sub>, 20 mM Tris-HCl pH 7.4), and purified by repeated passages on *E. coli* DH5αF'.

[0100] Proteins produced by recombinant phages were analyzed by Western blot. Plaque-purified recombinant phages were plated in soft agar, in the presence of 10 mM IPTG. The plates were incubated for 4h at 42°C, and then one night at 37°C. Approximately 10 plaques of each recombinant phage were removed and suspended in 100 μl of SDS gel-loading buffer (0.125 M Tris-HCl pH 6.8, 5 % SDS, 20 % glycerol, 10% β-mercaptoethanol, and 0.05 % bromophenol blue).

[0101] Isolation of recombinant phages coding for *M. tuberculosis*-specific proteins. Recombinant lambda ZAPII phages carrying mycobacterial DNA sequences were screened with a pool of tuberculosis patients sera: 21 strongly reactive clones were selected out of some 100,000 plaques. These clones were retested with anti-A60 polyclonal serum: some 16 positive clones were selected, and their expression products were then tested with the same pool of tuberculosis patients sera preabsorbed on lysates of non-tuberculous mycobacteria (MAIS strains, *M. avium*, and *M. leprae* strains). One phage (ZAP-Tb22) expressed a product strongly reacting with patients' sera and specific for *M. tuberculosis*, with respect to the other mycobacterial species. Western blot analysis of proteins from the lysis plaques of the recombinant phage showed two bands of 65 and 55 kDa reacting with tuberculosis patients sera (Fig. 1).

[0102] Analysis of the Tb22 region of recombinant mycobacterial DNA. Recombinant phage ZAP-Tb22 carrying a mycobacterial DNA segment was amplified. Its DNA was purified and hydrolyzed with *EcoRI* endonuclease, yielding a DNA insert of about 3,700 bp (Tb22) as determined by gel electrophoresis. The DNA sequence of the Tb22 insert was determined (see figures 2 and 3).

[0103] The expression of Tb22 was analysed by subcloning the restriction fragments of the insert in the members of an expression vectors family (pmTNFXH I, II and III; Innogenetics, Ghent, Belgium). A map of these vectors is shown in figure 10. These constructs allow the translation of the cloned genes in the 3 reading frames, as N-terminal fusion proteins with the first 25 amino acids of mouse tumor necrosis factor α, under the control of the pl lambda promoter (see also Gilot et al. 1993). Three of the analyzed constructs proved to be particularly interesting. Thus, a 1170 bp *EcoRI* DNA fragment, subcloned in vector pmTNFIIXH, yielded a recombinant plasmid (pmTNFXH.a390) which expressed the initial part of a gene comprised in Tb22, from now on called the b2 gene. The adjacent 2411 bp-*EcoRI* segment sub-cloned in the same vector (plasmid pmTNFXH.a171) expressed a further portion (513 bp) of the same gene. However, this same DNA fragment, upon insertion in vector pmTNFIIIXH (plasmid pmTNFXH.a389), which allows expression of a different reading frame on the same strand, expressed a 1167 bp product, forming part of a second gene comprised in the Tb22 clone (gene b3).

[0104] These results indicated that the Tb22 insert of mycobacterial DNA carried two partly overlapping ORF's (ORF1 corresponding to the b2 gene and ORF2 corresponding to the b3 gene), which were transcribed and translated into protein fragments in the recombinant strains. The overall expression product of Tb22 contained two different proteins corresponding to the partly overlapping reading frames ORF1 and ORF2 depicted in figures 2 and 3. The subsequent examples will demonstrate that fragments of both proteins (B2 and B3) are recognized by a pool of tuberculous sera, and contain species specific epitopes useful in the serodiagnosis of tuberculosis.

### III. Characterization and expression of the b2 gene (ORF1)

[0105] Base composition and expression of the B2 gene. According to the nucleotide sequence of the 3,700 bp Tb22 insert, and to the open reading frame ORF1 (in phase with the α-peptide gene of lambda ZAP), a DNA segment of 1551 bp was delineated (Fig.2). This segment extended from an ATG triplet at position 398 to a TAG triplet at position 1949, representing the putative (second) start and stop signals of gene b2, respectively.

[0106] The overall base composition of the b2 gene (63,5 mol% of G+C), was consistent with the global G+C content observed in the mycobacterial genome. The G+C contents for codon positions 1, 2, and 3 were 64.8, 47.5, and 74.3 mol%, respectively. These data agree with the codon usage described for the few known genes of the *M. tuberculosis* complex, and confirm the preference for either G or C in the third position.

[0107] A search for regulatory sequences within the nucleotide stretch preceding the b2 start codon at 398, revealed the presence of an AG-rich segment (G<sub>389</sub>AAGG<sub>393</sub>) resembling the Shine-Dalgarno consensus elements found in several bacteria, and also of promoter-like sequences (Hawley and McClure, 1983) mimicking those previously described

in *E.coli*.

[0108] The  $\alpha$ -peptide Tb22 fusion protein (corresponding to the Tb22 insert) had a calculated size of 62,990 Da, in agreement with a molecular mass of about 66 kDa determined by Western blotting (size of  $\alpha$ -peptide= 3864 Da). However, the expression of the entire ORF1 in *E.coli* under the control of a strong promoter was unsuccessful, presumably because entailing the synthesis of a protein detrimental for the host cell. To circumvent this difficulty, two plasmids were constructed: pmTNF.XH.a390 containing the first 390 codons of ORF1, and pmTNF.XH.a171 including the 171 carboxyl-terminal codons of ORF1, both expressed under the control of the pl lambda promoter (Fig. 4). Exponential SDS-PAGE bands of 45- and 25-kDa respectively (data not shown), in agreement with the values calculated from the DNA sequence. In Western blot analysis, only the 25-kDa product mTNF-a171 was recognized by the pool of tuberculosis sera (Fig. 4, line C), suggesting the occurrence of B cell epitopes in the carboxyl-terminal portion of the B2 protein. The species-specificity of these epitopes was verified in Western blots with tuberculosis patients sera pre-absorbed with sonicates of either *M.leprae* or *M. avium* strains (Fig. 4, line D). Persistence of the positive signal upon serum pre-absorption proved the B2 protein to have *M.tuberculosis*-specific epitopes non crossreacting with other mycobacterial species.

[0109] The hydrophilicity pattern of the B2 protein is illustrated on figure 8. According to this profile a predicted antigenic peptide K-14-R was synthesised. Antibodies were raised against this peptide in rabbits according to the method described in example 1.

[0110] Cloning of the DNA segment preceding the b2 gene. To confirm the structure of the mycobacterial DNA segment including the origin of the b2 gene, and to explore the possible occurrence of additional regulatory elements in this region, 10- to 12-kb-DNA fragments from a *M.tuberculosis* H37RV gene bank, were ligated with the lambda DASH cloning vector, using BamH1 linkers. One phage, out of some 4,000 plaques screened by *in situ* hybridization with the Tbbiot1 probe (carrying the initial sequence of the Tb22 insert), yielded a 0.9-kb Sal1-Pst1 DNA fragment (Tb3). The latter was subcloned in the vector pbluescript SK- and sequenced. Inspection of the sequence reported in Fig.2 revealed another putative starting codon for the b2 gene at position 71 preceded by a putative Shine-Dalgarno element (G<sub>60</sub>AGA<sub>63</sub>).

#### IV. Characterization and expression of the b3 gene (ORF2)

[0111] Base composition and expression of the b3 gene. A segment of the Tb22 insert, which would account for a translation product of an open reading frame (ORF2) different than that of b2 was sought in the sequence map of Fig. 2. A 1539 bp-long sequence, partly overlapping that of b2/ORF1 and involving the same strand in the same direction was thus identified. The corresponding gene (b3) extended from a putative initiation TTG triplet at position 1063 to a presumptive stop codon TAG at position 2602. The initiation codon of b3 was located 665 bp downstream that of b2, with a 886 bp overlap of the two genes. A search for regulatory sequences preceding the TTG<sub>792</sub> codon suggested the presence of a putative Shine-Dalgarno-like element (G<sub>1054</sub>GTGG<sub>1058</sub>), the presumptive translation initiation signal of ORF2.

[0112] A plasmid containing the terminal 1167 bp of ORF2 under the control of the pl lambda promoter (pmTNF.XH.a389) was constructed and introduced by transformation in *E. coli* SG4044 cells. The lysates of these recombinant cells, submitted to Western blot analysis with a tuberculous sera pool, showed a 42 kDa-band (Fig.5), in agreement with the value calculated from the DNA sequence. These data indicate that the expression product of gene b3 contained B cells epitopes recognized by tuberculous human sera. The species-specificity of these epitopes was tested as for the ORF1 product. Persistence of positive signal after serum pre-absorption indicates the presence, in the a389 protein, of epitopes specific for *M.tuberculosis* and not shared by other mycobacterial species.

[0113] The hydrophilicity pattern of the B3 protein is illustrated on figure 9. According to this profile a predicted antigenic peptide G-17-R was synthesised. Antibodies were raised against this peptide in rabbits according to the method described in example 1.

#### V. Development of an a171-based serological assay for tuberculosis.

[0114] Large scale preparation of the recombinant a171 polypeptide, coded for by gene b2, was based on the expression of this protein in *E.coli* under the form of inclusion bodies. The corresponding cellular fraction was separated from the crude lysate by centrifugation and solubilized. The results of an electrophoretic analysis of the partly purified fraction is shown in Fig. 6. This recombinant product was used to coat microtiter plates. Reference plates were coated with the A60 antigen, the natural mycobacterial antigen complex containing protein B2, in addition to several other proteins. Antigen A60 was prepared according to Cocito and Vanlinden (1986). A series of sera from healthy subjects (non vaccinated and BCG-vaccinated), and patients (56 persons with different forms of tuberculosis) were tested. Data displayed in Fig.7 indicate that most tuberculous sera positive with the A60-ELISA were also positive with the a171-ELISA.

which thus represents a species-specific serological assay for tuberculosis.

[0115] Based on the production of a B2 protein segment as inclusion bodies in recombinant *E.coli*, the a171 polypeptide corresponding to the carboxyl-terminal portion of B2 has been purified and used as reagent for a serological assay (a171-ELISA) for tuberculosis. According to this preliminary trial, the test was negative for healthy subjects and positive for tuberculosis patients. Although, a larger clinical work, extended to all forms of tuberculosis, is needed to assess the medical importance of this assay, our data suggest that the a171-ELISA, a test endowed with species-specificity, is a promising tool allowing the etiological diagnosis of tuberculosis. Indeed, most of the available immunoassays, including the A60 ELISA previously developed (Baelden et al., 1990; Cocito, 1991), are unable to distinguish tuberculosis from the other mycobacterioses. Yet, such a distinction is important, especially since the prognosis and therapy of mycobacterial diseases are different depending on the mycobacterial species causing the disease.

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Zou, Y. L., M. P. Van Antwerpen, G. Q. Shi, Q. X. Chen, C. J. M. Sindic, and C. Cocito. 1994a. Analysis of tuberculous meningitis cases by an immunoblotting assay based on a mycobacterial antigen complex. Clin. Diagn. Labor. Immunology. 1:353-356.

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

- (A) NAME: Innogenetics N.V.
- (B) STREET: Industriepark Zwijnaarde 7, box 4
- (C) CITY: Ghent
- (E) COUNTRY: Belgium
- (F) POSTAL CODE (ZIP): B-9052
- (G) TELEPHONE: 00 32 9 241 07 11
- (H) TELEFAX: 00 32 9 241 07 99

(ii) TITLE OF INVENTION: New polypeptides and nucleic acids encoding the same for the diagnosis and prevention of tuberculosis disease.

(iii) NUMBER OF SEQUENCES: 9

(iv) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: PatentIn Release #1.0, Version #1.30 (EPO)

(v) CURRENT APPLICATION DATA:

APPLICATION NUMBER: EP 98870127.2

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2708 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 71..1951

(ix) FEATURE:

- (A) NAME/KEY: mat\_peptide
- (B) LOCATION: 71..1948

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1063..2599

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- (A) NAME/KEY: mat\_peptide
- (B) LOCATION: 1063..2596

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

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	Val	Ser	Val	Ala	Tyr	Gln	His	Val	Arg	Glu	Asp	Pro	Ile	Pro	Pro	Ser	
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	GCG	CGG	CAC	GAA	GGC	CTC	TCC	GCC	GAC	CTG	GAC	GCC	GTC	GTT	CTC	AAG	829
	Ala	Arg	His	Glu	Gly	Leu	Ser	Ala	Asp	Leu	Asp	Ala	Val	Val	Leu	Lys	
50			240					245					250				
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		255				260											

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	GGTTGAACAC GAAGCTGTCTG TAGTTGTCAA CGACCAGGAT CCGCATCGTG ACAGGCTACC			2641
40	GCCTGACCCT GCCGGCAGTC GTTCAAGTAGT CCAAGGGGCC TGCAGGCTGC GCGAAGTGCA			2701
	TCCGGAC			2708

(2) INFORMATION FOR SEQ ID NO: 2:

- (1) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 627 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: protein
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

Met	Thr	Thr	Pro	Ser	His	Leu	Ser	Asp	Arg	Tyr	Glu	Leu	Gly	Glu	Ile
1						5			10					15	

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 Asp Pro Ser Phe Tyr Leu Arg Phe Arg Arg Glu Ala Gln Asn Ala Ala  
                     50                    55                    60  
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                     65                    70                    75                    80  
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                     85                    90                    95  
 15 Gly Val Thr Leu Arg Asp Ile Val His Thr Glu Gly Pro Met Thr Pro  
                     100                    105                    110  
 Lys Arg Ala Ile Glu Val Ile Ala Asp Ala Cys Gln Ala Leu Asn Phe  
                     115                    120                    125  
 20 Ser His Gln Asn Gly Ile Ile His Arg Asp Val Lys Pro Ala Asn Ile  
                     130                    135                    140  
 Met Ile Ser Ala Thr Asn Ala Val Lys Val Met Asp Phe Gly Ile Ala  
                     145                    150                    155                    160  
 Arg Ala Ile Ala Asp Ser Gly Asn Ser Val Thr Gln Thr Ala Ala Val  
                     165                    170                    175  
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                     180                    185                    190  
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                     195                    200                    205  
 30 Val Leu Thr Gly Glu Pro Pro Phe Thr Gly Asp Ser Pro Val Ser Val  
                     210                    215                    220  
 Ala Tyr Gln His Val Arg Glu Asp Pro Ile Pro Pro Ser Ala Arg His  
                     225                    230                    235                    240  
 35 Glu Gly Leu Ser Ala Asp Leu Asp Ala Val Val Leu Lys Ala Leu Ala  
                     245                    250                    255  
 Lys Asn Pro Glu Asn Arg Tyr Gln Thr Ala Ala Glu Met Arg Ala Asp  
                     260                    265                    270  
 40 Leu Val Arg Val His Asn Gly Glu Pro Pro Glu Ala Pro Lys Val Leu  
                     275                    280                    285  
 Thr Asp Ala Glu Arg Thr Ser Leu Leu Ser Ser Ala Ala Gly Asn Leu  
                     290                    295                    300  
 45 Ser Gly Pro Arg Thr Asp Pro Leu Pro Arg Gln Asp Leu Asp Asp Thr  
                     305                    310                    315                    320  
 Asp Arg Asp Arg Ser Ile Gly Ser Val Gly Arg Trp Val Ala Val Val  
                     325                    330                    335  
 50 Ala Val Leu Ala Val Leu Thr Val Val Val Thr Ile Ala Ile Asn Thr  
                     340                    345                    350  
 Phe Gly Gly Ile Thr Arg Asp Val Gln Val Pro Asp Val Arg Gly Gln  
                     355                    360                    365

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Ser Ser Ala Asp Ala Ile Ala Thr Leu Gln Asn Arg Gly Phe Lys Ile  
370 375 380

Arg Thr Leu Gln Lys Pro Asp Ser Thr Ile Pro Pro Asp His Val Ile  
385 390 395 400

Gly Thr Asp Pro Ala Ala Asn Thr Ser Val Ser Ala Gly Asp Glu Ile  
405 410 415

Thr Val Asn Val Ser Thr Gly Pro Glu Gln Arg Glu Ile Pro Asp Val  
420 425 430

Ser Thr Leu Thr Tyr Ala Glu Ala Val Lys Lys Leu Thr Ala Ala Gly  
435 440 445

Phe Gly Arg Phe Lys Gln Ala Asn Ser Pro Ser Thr Pro Glu Leu Val  
450 455 460

Gly Lys Val Ile Gly Thr Asn Pro Pro Ala Asn Gln Thr Ser Ala Ile  
465 470 475 480

Thr Asn Val Val Ile Ile Ile Val Gly Ser Gly Pro Ala Thr Lys Asp  
485 490 495

Ile Pro Asp Val Ala Gly Gln Thr Val Asp Val Ala Gln Lys Asn Leu  
500 505 510

Asn Val Tyr Gly Phe Thr Lys Phe Ser Gln Ala Ser Val Asp Ser Pro  
515 520 525

Arg Pro Ala Gly Glu Val Thr Gly Thr Asn Pro Pro Ala Gly Thr Thr  
530 535 540

Val Pro Val Asp Ser Val Ile Glu Leu Gln Val Ser Lys Gly Asn Gln  
545 550 555 560

Phe Val Met Pro Asp Leu Ser Gly Met Phe Trp Val Asp Ala Glu Pro  
565 570 575

Arg Leu Arg Ala Leu Gly Trp Thr Gly Met Leu Asp Lys Gly Ala Asp  
580 585 590

Val Asp Ala Gly Gly Ser Gln His Asn Arg Val Val Tyr Gln Asn Pro  
595 600 605

Pro Ala Gly Thr Gly Val Asn Arg Asp Gly Ile Ile Thr Leu Arg Phe  
610 615 620

Gly Gln \*

(2) INFORMATION FOR SEQ ID NO: 3:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 513 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

Leu Gly Cys Gly Gly Arg Arg Ala Arg Cys Ala Asp Arg Arg Gly Asn  
1 5 10 15

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His Arg His Gln His Val Arg Arg His His Pro Arg Arg Ser Ser Ser  
 20 25 30  
 5 Arg Arg Ser Gly Ser Ile Leu Arg Arg Arg His Arg His Thr Ala Lys  
 35 40 45  
 Pro Gly Leu Gln Asn Pro His Leu Ala Glu Ala Gly Leu Asp Asn Pro  
 50 55 60  
 10 Thr Gly Pro Arg Tyr Arg His Arg Pro Gly Arg Gln His Val Gly Glu  
 65 70 75 80  
 Cys Arg Arg Arg Asp His Ser Gln Arg Val His Arg Thr Gly Ala Thr  
 85 90 95  
 15 Arg Asn Thr Arg Arg Leu His Ala Asp Ile Arg Arg Ser Gly Gln Glu  
 100 105 110  
 Thr Asp Cys Arg Arg Ile Arg Pro Leu Gln Ala Ser Glu Phe Ala Val  
 115 120 125  
 His Pro Gly Thr Gly Gly Gln Gly His Arg Asp Gln Pro Ala Ser Gln  
 130 135 140  
 20 Pro Asp Val Gly His His Gln Cys Gly His His His Arg Trp Leu Trp  
 145 150 155 160  
 Ser Gly Asp Gln Arg His Ser Arg Cys Arg Gly Pro Asp Arg Arg Arg  
 165 170 175  
 25 Gly Ala Glu Glu Pro Gln Arg Leu Arg Leu His Gln Ile Gln Ser Gly  
 180 185 190  
 Leu Gly Gly Gln Pro Pro Ser Arg Arg Arg Gly Asp Arg His Gln Ser  
 195 200 205  
 30 Thr Arg Arg His His Ser Ser Gly Arg Phe Ser His Arg Thr Thr Gly  
 210 215 220  
 Val Gln Gly Gln Pro Ile Arg His Ala Arg Pro Ile Arg His Val Leu  
 225 230 235 240  
 35 Gly Arg Arg Arg Thr Thr Ile Ala Arg Ala Gly Leu Asp Arg Asp Ala  
 245 250 255  
 Arg Gln Arg Gly Arg Arg Arg Arg Arg Trp Leu Pro Thr Gln Pro Gly  
 260 265 270  
 40 Arg Leu Ser Lys Pro Ala Gly Gly Asp Arg Arg Gln Pro Gly Arg His  
 275 280 285  
 His His Ala Glu Val Arg Pro Val Ala Ser Pro Ala Leu Ala Val Glu  
 290 295 300  
 45 Val Gly Lys Ser Gly Glu Met Ala Val Ser Thr Ser Phe Ser Ser Arg  
 305 310 315 320  
 Arg Thr Arg Val Ser Ser Cys Val His Pro Gln Gln Val Ser Gln Leu  
 325 330 335  
 50 Ala Ser Met Arg Cys Pro Pro Ser Val Arg Ile Asp Ser Gly Trp Asn  
 340 345 350  
 Trp Thr Pro Trp Ile Gly Ser Pro Val Cys Cys Thr Ala Met Ile Thr  
 355 360 365

55

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Pro Leu Leu Val Arg Ala Val Thr Leu Ser Thr Ala Gly Ser Asp Leu  
 370 375 380  
 Gly Arg Ile Phe Asn Glu Trp Tyr Arg Val Ala Val Lys Gly Ser Gly  
 385 390 395 400  
 Ser Pro Cys Ser Thr Pro Thr Leu Val Trp Asn Thr Leu Leu Val Leu  
 405 410 415  
 Pro Cys Asn Ser Ser Gly Ala Arg Ser Thr Val Ala Pro Asn Ala Thr  
 420 425 430  
 Pro Met Ala Trp Cys Pro Arg Gln Thr Pro Ser Lys Gly Val Cys Ala  
 435 440 445  
 Ala Ala His Ala Cys Thr Ile Leu Thr Asp Ala Pro Ala Arg Ser Gly  
 450 455 460  
 Val Pro Gly Pro Gly Leu Ser Arg Thr Pro Ser Asn Trp Pro Ala Thr  
 465 470 475 480  
 Ala Ala Ser Ser Asp Asn Arg Trp Ser Ser Leu Arg His Thr Ser Ala  
 485 490 495  
 Ser Met Pro Ser Trp Pro Arg Tyr Cys Thr Arg Leu Asn Thr Lys Leu  
 500 505 510  
 Ser

## (2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 14 amino acids
  - (B) TYPE: amino acid
  - (C) STRANDEDNESS:
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

Lys Gly Ala Asp Val Asp Ala Gly Gly Ser Gln His Asn Arg  
 1 5 10

## (2) INFORMATION FOR SEQ ID NO: 5:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 17 amino acids
  - (B) TYPE: amino acid
  - (C) STRANDEDNESS:
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

Gly Gln Pro Pro Ser Arg Arg Arg Gly Asp Arg His Gln Ser Thr Arg  
1 5 10 15  
Arg

(2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 21 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

GCGGGCGTT TCGGCTTCAC C

(2) INFORMATION FOR SEQ ID NO: 7:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 132 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

CAGGGAATTC GAGCTCGGTA CCCGGGGAGG CCTGCACGTG ATCGAGGGCA GACACCATCA 60

CCACCATCAC TAATAGTTAA TTAAGTGCAG GGATCCTCTA GAGTCGACCG GCATGCAAGC 120

TTAAGTAAGT AA

(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 133 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

CAGCCGAATT CGAGCTCGGT ACCCGGGGAG GCCTGCACGT GATCGAGGGC AGACACCATC 60  
 ACCACCATCA CTAATAGTTA ATTAAGTCA GGGATCCTCT AGAGTCGACC GGCATGCAAG 120  
 CTTAAGTAAG TAA 133

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 134 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

CAGCCCGAAT TCGAGCTCGG TACCCGGGGA GGCCTGCACG TGATCGAGGG CAGACACCAT 60  
 CACCACCATC ACTAATAGTT AATTAAGTGC AGGGATCCTC TAGAGTCGAC CGGCATGCAA 120  
 GCTTAAGTAA GTAA 134

#### Claims

1. An isolated nucleic acid of *M. tuberculosis* containing a nucleotide sequence with a maximum length of 3000 contiguous nucleotides, wherein said nucleotide sequence contains at least two overlapping ORF's which encode at least a fragment of the following two antigenic proteins recognized by a pool of sera from tuberculous patients:

(i) a B2 protein represented by SEQ ID NO 2, or a protein homologous to B2 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID NO 2, and

(ii) a B3 protein represented by SEQ ID NO 3, or a protein homologous to B3 containing in its amino acid sequence at least one conservative amino acid substitution (according to Table 1) with respect to the sequence represented by SEQ ID NO 3,

or a fragment of said nucleic acid, said fragment containing at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence of said nucleic acid, and encoding at least one epitope of the B2 and/or B3 protein, or its homologues.

2. An isolated nucleic acid according to claim 1, wherein said nucleotide sequence is selected from:

- (i) the nucleotide sequence as represented in figure 2 (SEQ ID NO 1),
  - (ii) a nucleotide sequence which hybridizes to the nucleotide sequence of (i) and which encodes a B2 protein, or a protein homologous to B2, and/or a B3 protein, or a protein homologous to B3, with said B2 (B3) protein and its homologues as defined in claim 1,
  - (iii) a nucleotide sequence which is degenerate as a result of the genetic code to any of the nucleotide sequences as defined in (i) and (ii) and which encodes a B2 protein, or a protein homologous to B2, and/or a B3 protein, or a protein homologous to B3, with said B2 (B3) protein and its homologues as defined in claim 1, and
  - (iv) a fragment of any of the nucleotide sequences as defined in (i) to (iii), said fragment containing a stretch of at least 15, preferably 30 and more preferably 45 contiguous nucleotides of any of the nucleotide sequences as defined in (i) to (iii), and encoding at least one epitope of the B2 and/or B3 protein, or the homologous proteins thereof.
3. An isolated nucleic acid according to any of claims 1 to 2, wherein said nucleotide sequence extends from position (x) to position (y) in the sequence of figure 2 (SEQ ID NO 1), with (x) and (y) representing any of the following values:
- from position (71) to position (1951),
  - from position (398) to position (1951),
  - from position (1063) to position (2604),
  - from position (272) to position (1438),
  - from position (1439) to position (1951),
  - from position (1438) to position (2604),
  - or a fragment of said nucleic acid, said fragment containing at least 15, preferably at least 30 and more preferably at least 45 contiguous nucleotides of the sequence of said nucleic acid, and encoding at least one epitope of the B2 and/or B3 protein.
4. A recombinant vector, for cloning and/or expression purposes, into which a nucleic acid according to any of claims 1 to 3, or a fragment of said nucleic acid, has been inserted and wherein, in case of an expression vector, the coding sequence of said nucleic acid is operably linked to an expression cassette enabling the expression of the coding sequence by a host cell.
5. A host cell transformed by a recombinant vector according to claim 4, with said host cell being preferably a prokaryotic organism, preferably chosen from among the following group of organisms: *E. coli*, *Streptomyces* species, *Corynebacterium* species, such as e.g. *C. glutamicum*, or fast-growing *Mycobacterium* species, such as e.g. *M. smegmatis*.
6. A polypeptide encoded by any of the nucleic acids according to claims 1 to 3.
7. A polypeptide according to claim 6, having at least one of the following amino acid sequences:
- (i) the amino acid sequence of the B2 protein represented by SEQ ID NO 2,
  - (ii) the amino acid sequence of the B3 protein represented by SEQ ID NO 3,
  - (iii) the amino acid sequence extending from position (110) to position (626) in SEQ ID NO 2,
  - (iv) the amino acid sequence extending from position (68) to position (456) in SEQ ID NO 2,
  - (v) the amino acid sequence extending from position (457) to position (626) in SEQ ID NO 2,
  - (vi) the amino acid sequence extending from position (126) to position (513) in SEQ ID NO 3,
  - or a fragment of any of the polypeptides according to (i) to (vi), said fragment consisting of a stretch of at least 6, preferably 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 30, 50 or more contiguous amino acids of the sequence represented by SEQ ID NO 2 or SEQ ID NO 3, and being recognized by a pool of sera from tuberculous patients.
8. A fusion protein comprising an amino acid sequence of a polypeptide according to any of claims 6 to 7, or a fragment thereof, linked to a heterologous amino acid sequence.
9. A method for the production of a recombinant polypeptide according to any of claims 6 to 7, or a fusion protein according to claim 8, comprising at least the following steps:

- culturing a transformed cellular host according to claim 5 under conditions allowing the heterologous expression of the polypeptide or the fusion protein which is encoded,
- isolating the polypeptide or fusion protein from the culture broth.

5 10. An antibody raised against a polypeptide according to any of claims 6 to 7, or raised against a fusion protein according to claim 8, more preferably a monoclonal antibody.

11. A method for the *in vitro* detection of tuberculosis disease in a mammal subject, based on the detection of anti- *M. tuberculosis* antibodies present in a sample taken from said subject, comprising the steps of

- 10
- contacting said sample with a polypeptide according to any of claims 6 to 7, or with a fusion protein according to claim 8, under conditions allowing the formation of an immunological complex, and
  - detecting the presence of an immunological complex formed between said polypeptide and the anti - *M. tuberculosis* antibodies which may be present in said sample.

15 12. A method for the *in vitro* detection of tuberculosis disease in a mammal subject, based on the detection of *M. tuberculosis* antigens present in a sample taken from said subject, and comprising the steps of

- 20
- if necessary, pretreatment of said sample in order to release the *M. tuberculosis* antigens which may be present in said sample,
  - contacting said sample with an antibody according to claim 10, under conditions allowing the formation of an immunological complex, and
  - detecting the presence of an immunological complex formed between said antibody and the *M. tuberculosis* antigens which may be present in said sample.

25 13. An immunodiagnostic kit for the *in vitro* detection of tuberculosis disease in mammals, said kit comprising a polypeptide according to any of claims 6 to 7, or a fusion protein according to claim 8, or an antibody according to claim 10.

30 14. A vaccine composition for the prevention of tuberculosis disease in mammals, said vaccine composition comprising as an active principle a polypeptide according to any of claims 6 to 7, or a fusion protein according to claim 8, or a nucleic acid according to any of claims 1 to 3, or a recombinant vector according to claim 4, said active principle being combined with a pharmaceutically acceptable carrier.

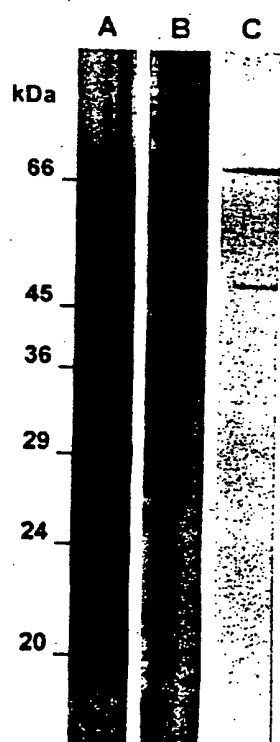


Figure 1



Figure 2

GACTGCAAAGCTGGGTTGTCCCGCCGACACCGCATTCGCGCGCGTCTGCTGGCCCCGATACGAGATAGCCCA 70

ATGACCACCCCTTCCACCTGTCCGACCGCTACGAACTTGGCGAAATCCTTGGATTGGGGGCATGTCCG 140  
M T T P S H L S D R Y E L G E I L G F G G M S E  
10 20  
← ORF1 (B2)

AGGTCCACCTGGCCCGGACCTCCGGTTGCACCGCGACGTTGCGGTCAAGGTGCTGCGCGCTGATCTAGC 210  
V H L A R D L R L H R D V A V K V L R A D L A  
30 40

CCGCGATCCAGTTTTACCTTCGCTTCGGGCTGAGGCGCAAAACGCGCGCATTTGAACCACTGCA 280  
R D P S F Y L R F R R E A Q N A A A L N H\* P A  
50 60 70  
2390

Tbb101  
ATCCTCGCGGTCTACGACACCGCTGAGCGGAAAGCGCGCGCATTTGCGCTACATCGTCAGGAT 250  
I V A V Y D T G E A E T P A S P L P Y I V M E Y  
80 90

Sall  
ACCTGGACGGCGTTACCTTCGCGGACATTGTCCACACCGAAGGCGCGATGACGCCCCAAGCGGCCATCGA 420  
V D G V T L R D I V H T E G P M T P K R A I E  
100 110

GCTCATCGCGGACGCGCTGCCAAGCGCTGAACTTCAGTCATCAGAACGGATCATCCACCGTGACGTCAAG 490  
V I A D A C Q A L N F S H Q N G I I R D V K  
120 130 140

CCGCGCAACATCATGATCAGCGCGACCAATGCAGTAAGGTGATGGATTTCGGCATCGCCCGCGCGCATTC 560  
P A N I M I S A T N A V K V M D F G I A R A I A  
150 160

CCGACAGCGGACACAGCGTGACCCAGACCGCAGCAGTGATCGGACCGCGCAGTACCTGTACCCGACAC 630  
D S G N S V T Q T A A V I G T A Q Y L S P E Q  
170 180

GGCCCGGGGTGATTCCGTGAGCGCCCGATCCGATGTCTATTGCTTGGGCTGTGTTCTTTATGAGTCTCT 700  
A R G D S V D A R S C V Y S L G C V L Y E V L  
190 200 210

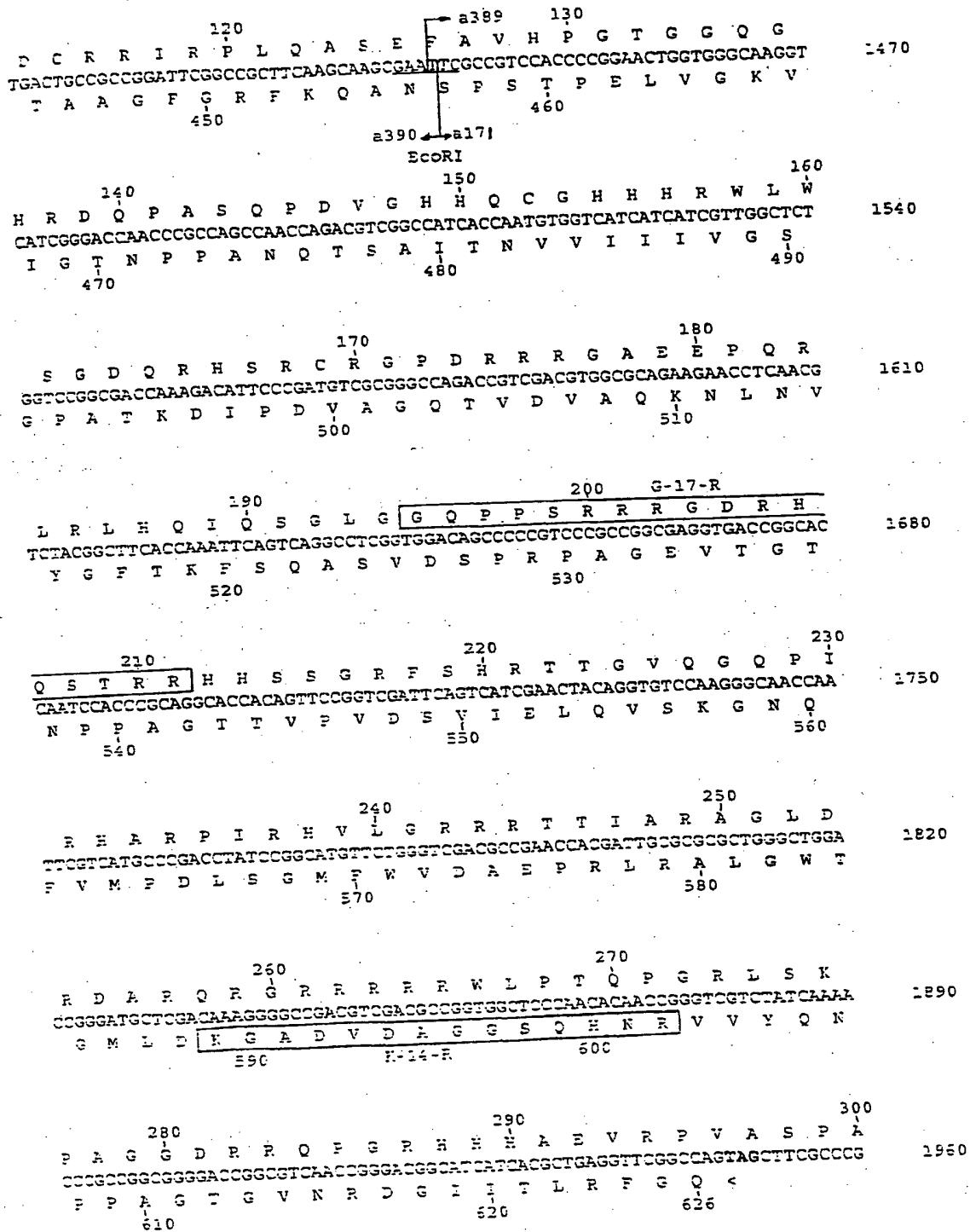
ACCGGGGAGCCACCTTTACCGCGGACTCACCCGTCTCGGTTGCGTACGACATGTGCGCGAAGACCCGA 770  
T G E P P F T G D E P V S V A Y T H V R E D P I  
220 230

Figure 2 (cont'd 1)

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Figure 2 (cont'd 2)



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Figure 2 (cont'd 3)

<sup>310</sup>  
 L A V E V G K S G E M A V S T S F S S R R T R <sup>320</sup>  
 CSCTAGCGGTTGAAGTTGGGAAGTCCGGTGAGATGGCGGTGAGCACTTCGTTTTCCAGCCGACGTACCAG 2030

<sup>330</sup>  
 V S S C V H P Q Q V S Q L A S M R C P P S V R <sup>340</sup>  
 GGTGTCGTCTTCCGTCCATCCGAGCAGGTGAGCCAGTTGGCCAGTATGCGGTGCCCGCCCTCGGTGAGA 2100

<sup>350</sup>  
 I D S G W N W T P W I G S P V C C T A M I T P L <sup>360</sup> <sup>370</sup>  
 ATCGACTCCGATGGAACTGGACACCGTGGATCGGCAGCCCGGTGTGCTGCACGGCCATGATCACACCGC 2170

<sup>380</sup>  
 L V R A V T L S T A G S D L G R I F N E W Y R <sup>390</sup>  
 TGCTAGTGCGGSCCGTGACCCCTCAGCACCGCTGGCAGCGACTTAGGCAGAAATTTCAACGAATGCTATCG 2240

<sup>400</sup>  
 V A V K G S G S P C S T P T L V W N T L L V L <sup>410</sup>  
 AGTGGCCGTGAAGGGGATCCGGAAGCCCTGTAGCACACCGACATTGGTGTGGAATACGCTGCTGCTCTTC 2310

<sup>420</sup>  
 P C N S S G A R S T V A P N A T P M A W C P R Q <sup>430</sup> <sup>440</sup>  
 CCGTGAATAGCTCGGGCGCACGGTCCACGGTGGCGCCGACGCAACGCCGATGGCTTGGTGCCCAAGSC 2380

<sup>450</sup>  
 T P S K G V C A A A H A C T I L T D A P A R S <sup>460</sup>  
 AGACCCCGACAAAGGGGTGTGTGCTGCCGACACGCGTGCACGATACTCACCGACGCGCCCGCGCGTC 2450

<sup>470</sup>  
 G V P G P G L S R T P S N W P A T A A S S D N <sup>480</sup>  
 CGGGGTACCCGGACCGGGACTGAGCAGGACACCGTGAATTGGCCGGCGACGGCGGCTCATCGGATAAC 2520

<sup>490</sup>  
 R W S S L R H T S A S M P S W P R Y C T R L N T <sup>500</sup> <sup>510</sup>  
 CGGTGGTGGTGGTGGCGCCACACCTCGGCCTCGATGCGGAGCTGGCCGAGGTACTGCACAGGTTGAACA 2590

<sup>513</sup>  
 K L S  
 CCAAGTGTCTAGTTGTGCAACGACAGGATCCGCTGTGACAGGCTACCGGCTGACCCCTGCGGCGAGT 2650

CGTTCACTAGTCCAAGGGGCTTGCAGGCTGCGCGAAGTGCATCCGGAC 2708

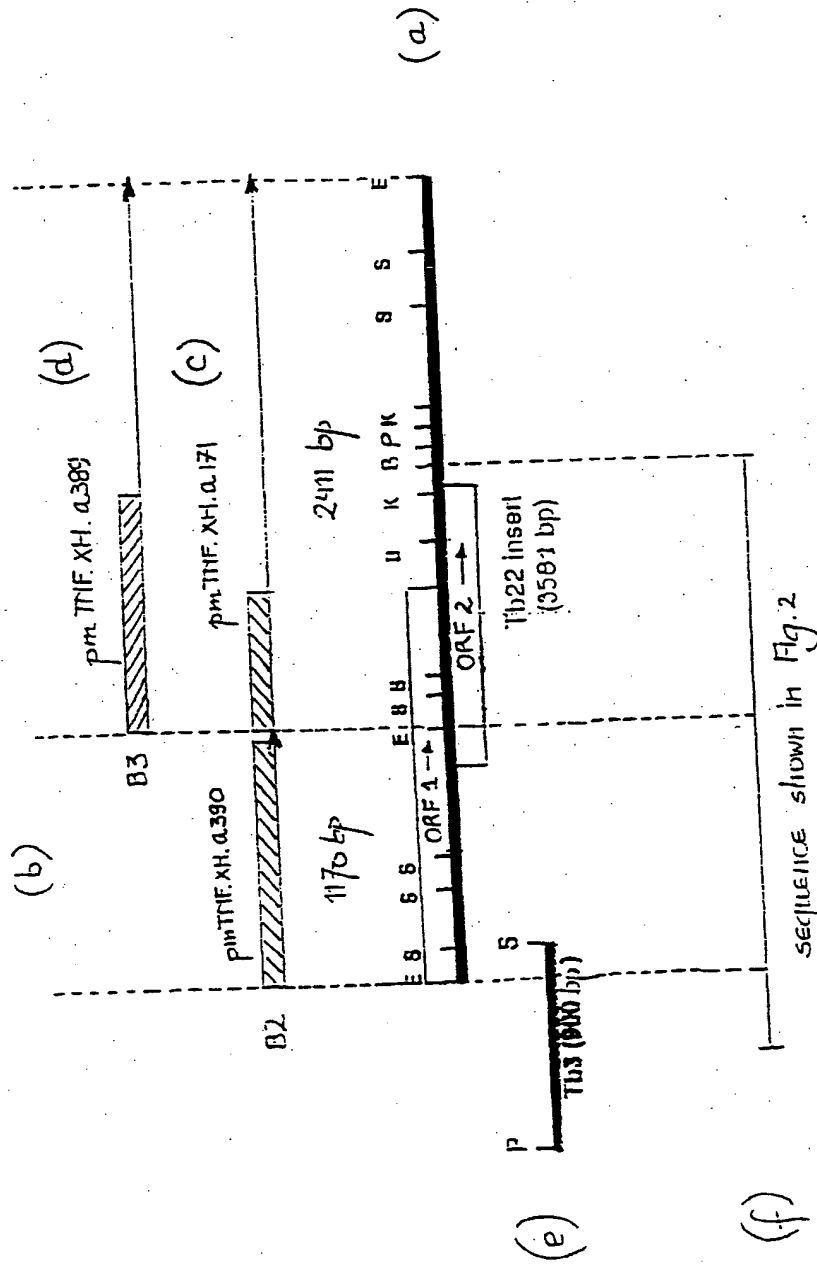


Figure 3

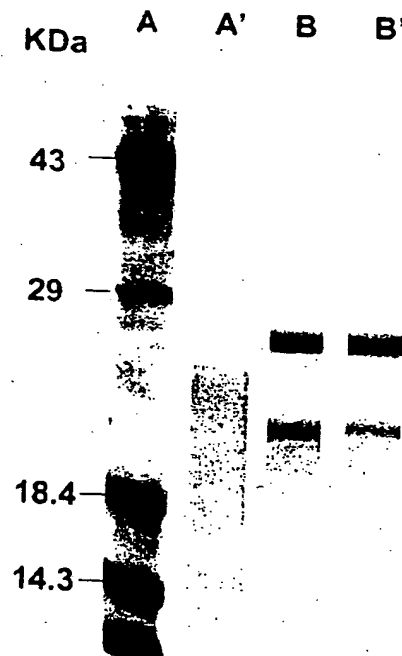


Figure 4

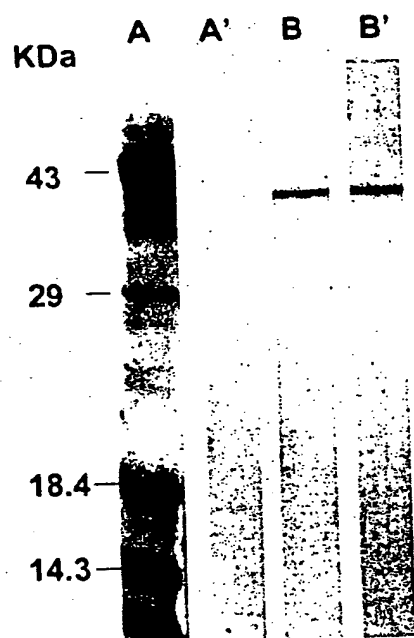


Figure 5



Figure 6



tbc post-primary    tbc miliary    tbc meningitis    tbc sera mixed    healthy controls    healthy BCG vace.

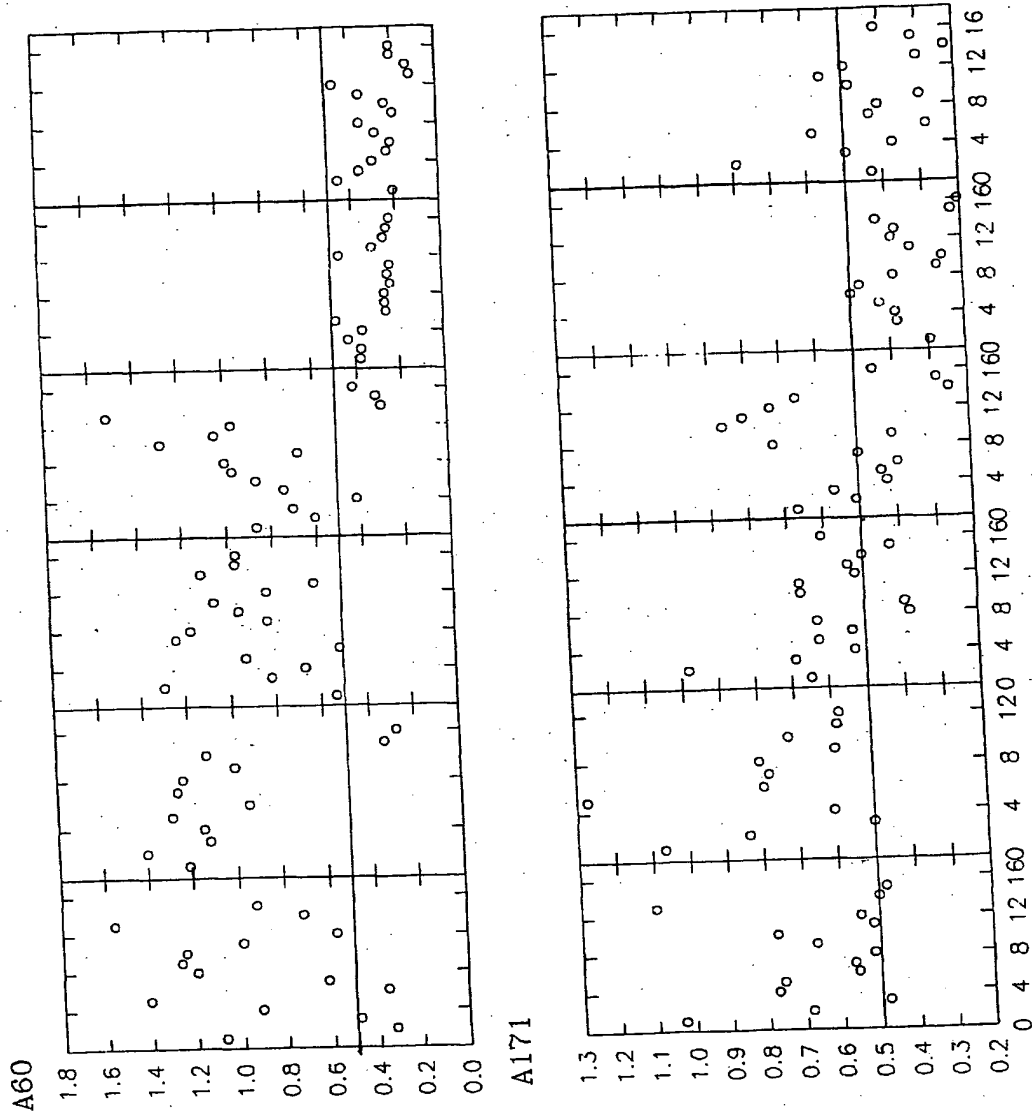


Figure 7

Hydrophilicity pattern of a fragment of the B2 protein

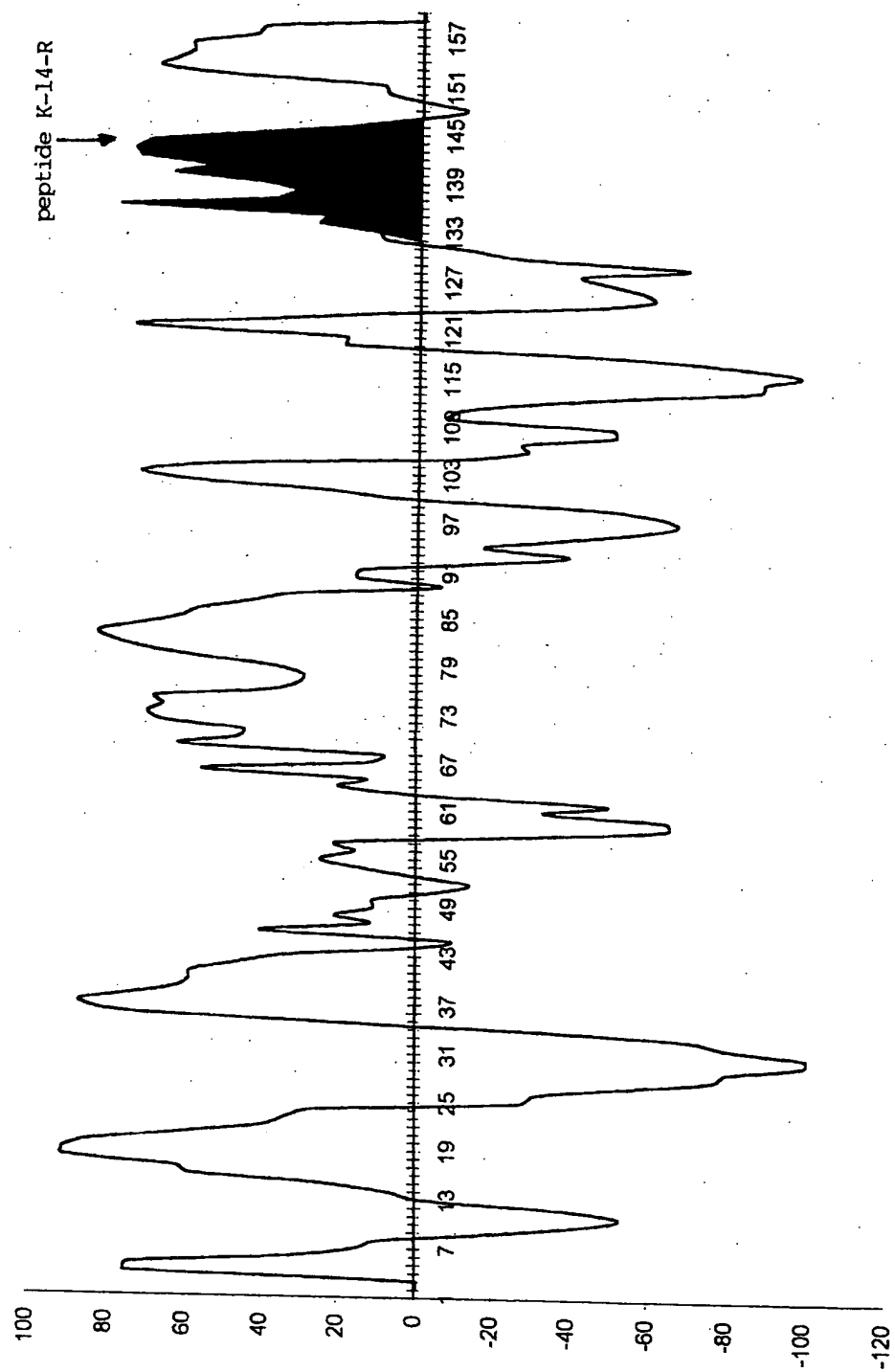


Figure 8

Hydrophilicity pattern of a fragment of the B3 protein

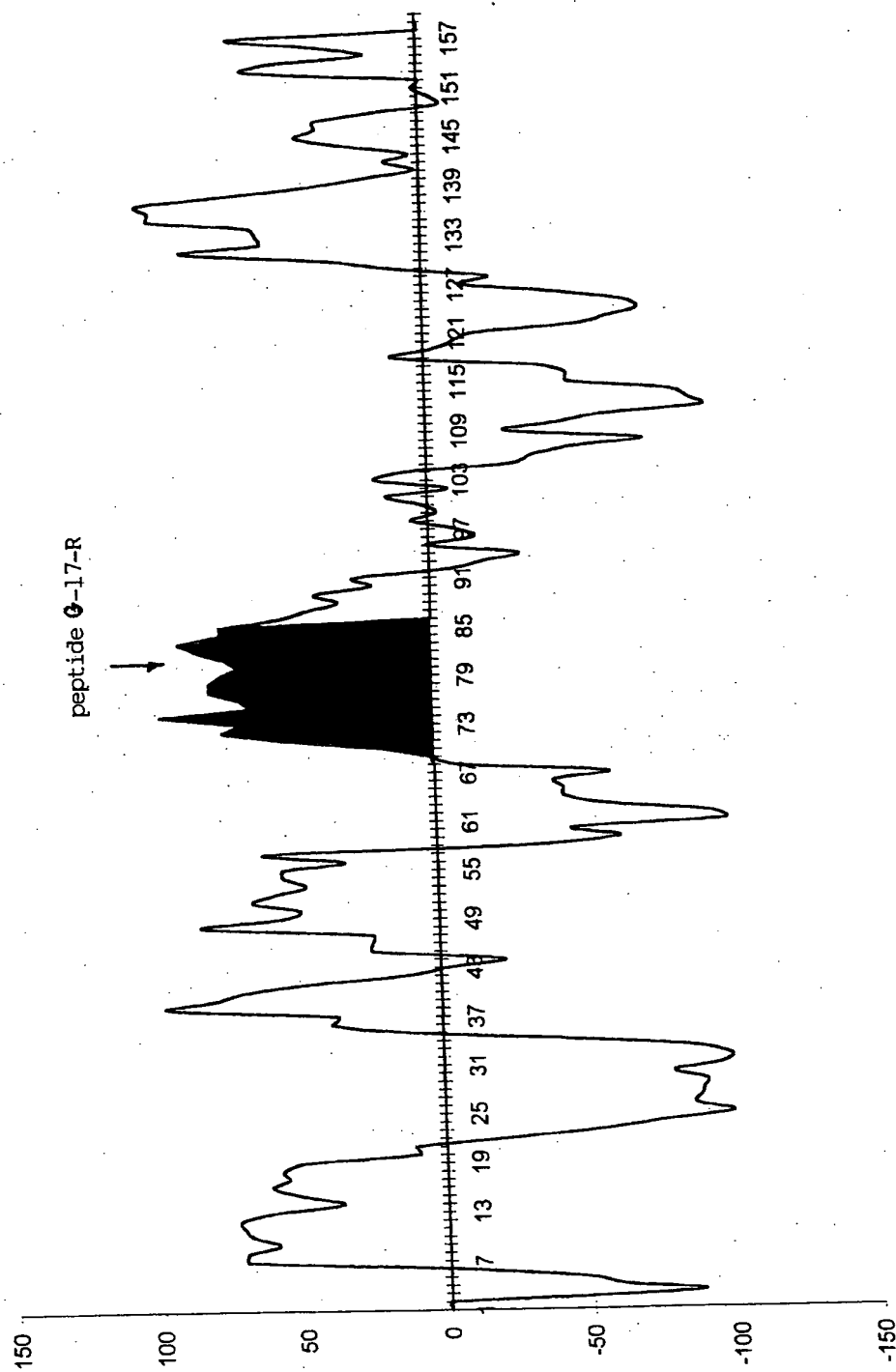


Figure 9

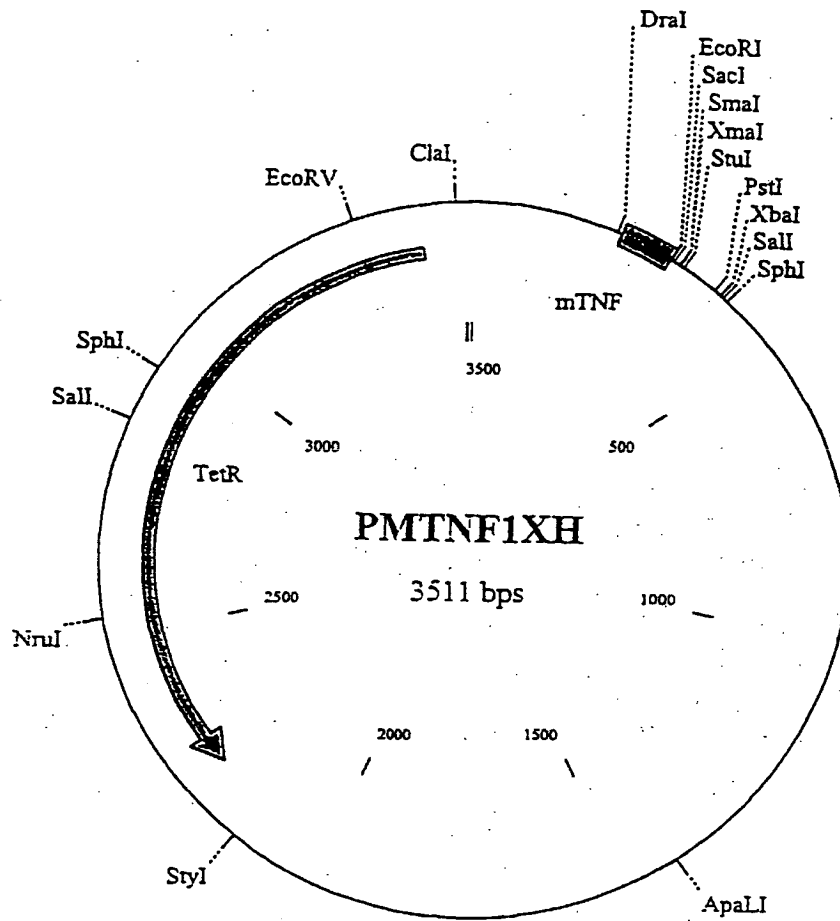


Figure 10



European Patent  
Office

# PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention EP 98 87 0127  
shall be considered, for the purposes of subsequent  
proceedings, as the European search report

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DATABASE EMBL Accession No. M33814, 30 June 1990 ESSAR D.W. ET AL.: XP002102734 * abstract *	1-10	C12N15/31 C07K14/35 C07K19/00 C07K16/12 G01N33/569
X	DATABASE EMBL Accession No. P71584, 1 January 1998 MURPHY L. ET AL.: XP002102735 * abstract *	1-10	
X	DATABASE EMBL Accession No. P54744, 1 October 1996 FSIHI H. ET AL.: XP002102736 * abstract *	1-10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			C12N C07K G01N
INCOMPLETE SEARCH			
<p>The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.</p> <p>Claims searched completely :</p> <p>Claims searched incompletely :</p> <p>Claims not searched :</p> <p>Reason for the limitation of the search:</p> <p>see sheet C</p>			
Place of search		Date of completion of the search	Examiner
MUNICH		14 May 1999	Chakravarty, A
CATEGORY OF CITED DOCUMENTS			
<p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03.82 (P04C07)



European Patent  
Office

INCOMPLETE SEARCH  
SHEET C

Application Number  
EP 98 87 0127

Claim(s) searched incompletely:  
1-10

Reason for the limitation of the search:

The claims of the present patent application do not comply with the requirements of Article 84 EPC to such an extent that it is not possible to carry out a meaningful search.

The Guidelines say explicitly that "no special search effort need be made for searching unduly wide or speculative claims" [Guidelines, B-III 3.7], and that the costs for the search are to be "kept within reasonable bounds" [Guidelines B-III 2.1 and 3.6].

In this case homologues (with 50% identity), of homologues (with 50% identity) of undefined fragments, of undefined fragments of a given (degenerate) sequence.

Moreover, such claims cannot be regarded as a "clear and concise description of the matter for which protection is sought".

The search has been limited to SEQ IDs 1-5 and to the examples.